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MiG Aircraft

since 1937

Bill Gunston & Yefim Gordon

When Artyom Ivanovich Mikoyan was appointed head of the Soviet Union's new experimental aircraft design department (OKO) in 1939, he accepted the post on the condition that another young designer, Mikhail Iosifovich Guryevich, could be his deputy. This was the start of a partnership that would last for almost thirty-five years. During this time, the name MiG would become famous the world over. In 1940, the pair's first fighter aircraft went into production. Designated the MiG-1, after the two designers, it was probably the first fighter to exceed 400mph in level flight. By the time Germany invaded the Soviet Union in June 1941, more than one-third of the country's fighters were MiGs. Soon after the Second World War, Britain foolishly sent to Moscow the world's most powerful turbojet, enabling the MiG company to develop the first Soviet swept-wing jet fighter, the MiG-15, then the most advanced in Europe. Once on top, the MiG team's talent and speed of reaction kept it there, and the company went on to produce some of the most feared high-performance military aircraft of the twentieth century. With the advent of *perestroika* in 1991, the MiG design bureau turned to civil aircraft in an attempt to find fresh markets and to keep its loyal workforce in employment. It is currently developing a number of prototypes, including the MiG-110 transport.

MiG Aircraft since 1937 reunites Bill Gunston, OBE, FRAeS, and Moscow-based Yefim Gordon, who previously worked together on *Yakovlev Aircraft since 1924*, also in the Putnam series. With their contacts in Russia, the authors have been allowed unprecendented access to the archives of both the former Soviet Union's design bureaux and the MiG company itself. As a result, they present here the first definitive and fully accurate work of reference on all the MiG designs, complete with hundreds of photographs and drawings – several of which have never been published before – as well as previously unrecorded details of MiG variants.

Cover illustration: An original painting by Wilfred Hardy G.AV.A. depicting two MiG-29As of a Soviet Air Force Frontal Aviation fighter regiment.

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A MiG-3 at an advanced Russian aerodrome during the Second World War. (Official USSR photograph)

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Bill Gunston
Yefim Gordon

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Also by Bill Gunston & Yefim Gordon from Putnam Aeronautical Books:

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Introduction

If every human were to be asked 'Name a type of aeroplane', it is a fair bet that the most common answer would be 'MiG'. To millions, this is the only 'name' they know. Of course, a MiG can be any of many types of aeroplane, but until very recently – when the previously unknown requirement to stay solvent led to a rash of *konversiya* projects – almost every MiG was a high-performance fighter.

During what Russians call the Great Patriotic War MiG fighters did not enjoy the massive success gained by those designed by Yakovlev and Lavochkin. Soon after the war, however, Britain shortsightedly sent to Moscow the most powerful turbojet then available in the world. This engine made possible the MiG-15, an aircraft which catapulted the name 'MiG' into the headlines. Once on top, the MiG design team's talent and speed of reaction kept it there, and it has been world-famous ever since.

The MiG team was organized in 1939 in a most politically charged way. Its story really started on 1 September 1934, however, when the Soviet Union's leading fighter designer, Nikolai Nikolayevich Polikarpov, watched Valerii P Chkalov make the first flight of the I-17. Powered by a water-cooled Hispano-Suiza engine, this fighter was more modern than the previous-generation I-16 but still had a mixed metal and wooden structure, with most of the wing and tail skinned in fabric. Polikarpov was already thinking about new airframes entirely of the all-metal stressed-skin type. He was also considering various more powerful engines.

One project, the I-19, or Central Construction Bureau No. 25 (CCB-25), would have been powered by the M-34RNF engine, a large liquid-cooled V-12 designed in A A Mikulin's bureau. Another was the I-172, CCB-43, powered either by a Hispano-Suiza or by the Soviet licensed M-103 or M-105 version when this became available. A third project was the I-18, powered by a compact radial engine, which promised better manoeuvrability.

Work went ahead on the I-18, initially as the I-180-1. Powered by a 950/1,000hp M-88 engine, this again retained traditional mixed wood/metal construction, but was an attractive fighter, far superior to the I-16 which equipped the VVS-RKKA (Air Force of the Red Workers' and Peasants' Army), and less tricky to fly. Tragically, on 15 December 1938 Chkalov climbed abroad, started up and took off on a test. Having been carelessly left uncovered all night in minus-14° C temperature, the engine seized. Trying to avoid obstructions, Chkalov was killed.

This was far more than the loss of a prototype. Chkalov was the most celebrated pilot in the USSR, and a national hero. Moreover, this was the time when Stalin's terror was building to a climax. Anyone famous, including every senior officer, ran the risk of being arrested, put through a show trial and either sent to rot in Siberia or given a bullet in the back of the head. How Polikarpov remained free is a mystery, though many of his designers were arrested, including the chief I-180 designer D L Tomashyevich, and several top men from the adjacent factory.

In the Western world, aircraft are designed by companies, and subsequently, if they are successful, are produced by them. In contrast, the Soviet Union organized its design teams into OKBs (experimental construction bureaux). Almost all OKBs had a workshop, but its job was merely to hand-build prototypes. If these succeeded in beating any rivals, they would be placed in series (quantity) production at a large factory possibly thousands of kilometres away.

The MiG OKB in 1943. (OKB)

Usually the OKB had no say in choosing the factory. It would be required to send a small team of engineers there to explain the drawings and to iron out possible manufacturing problems, but would otherwise play no part in series production.

Polikarpov's OKB was most unusual, in that it was located at Khodynka, formerly called Moscow Central Airfield, alongside GAZ (State Aviation Factory) No. 1, the country's oldest aircraft production centre. It was sometimes called Aviakhim Factory No. 1, because the aviation and chemical industries had originally been lumped together for bureaucratic purposes.

Back in 1929 Polikarpov's prominence had earned him the dubious honour of being the very first Soviet aircraft designer to be arrested and put to work in a special prison. He was released in 1933 to head the fighter team at the new Central Construction Bureau, at GAZ No. 1. In 1936 he had been further burdened by being made chief designer at both GAZ No. 21 at Gor'kiy and GAZ No. 84 at Moscow Khimki, but Chkalov's death instantly put him under a cloud. This was a time of intrigue and fear, but for the moment at least he was able to continue working.

Accordingly, in early 1939, in addition to several large existing programmes, he began work on two projected fighters. One was the ITP (fighter with heavy cannon). The other was called simply Aircraft X. X in Russian is translated as Kh in English; for example, we spell Xarkov as Kharkov. Aircraft Kh was to be a high-altitude interceptor, powered by the latest engine from Mikulin, the AM-37, a massive V-12 rated at 1,400hp.

Like other late Polikarpov designs, Aircraft Kh still retained a modernized form of the traditional mixed construction. In appearance it was a typical Polikarpov fighter, which took shape rapidly on the drawing boards of Polikarpov himself, his deputy, M N Tetivkin, and several draughtsmen. Polikarpov was told it was planned for production at GAZ No. 21, whose director assisted in working out the details of what today would be called modular construction, the aircraft being designed to be quickly assembled or dismantled at bolted joints.

While he was thus engaged, the political machinery began to roll. In early 1939 the Messerschmitt Bf 109E, which was in full production, was in most respects significantly better than any Soviet fighter prototype then flying, and far superior to the fighters in VVS-RKKA service. In May 1939 fierce air battles over Mongolia demonstrated the superiority of Japanese fighters. Stalin fumed, and fighter designers were summoned to the Kremlin. The NKAP (People's Commissariat for Aircraft Production) decided that, even though there were already nine Soviet design teams engaged on single-engined fighters, a new team should be formed to rush through a superior fighter. This team would not be a full OKB but an OKO (experimental design department), staffed by the most talented of the country's young designers.

The accent on the young was a reaction against the supposed sluggishness of the older designers (though how anyone could level this charge at Polikarpov beggars belief, because among other things he was directing design and development of six types of single- and twin-engined fighters). Some writers have suggested that after Chkalov's death, and the loss of the next two I-180 prototypes (though neither was attributed to failure of the aircraft), Polikarpov lost confidence in himself.

Be that as it may, in the prevailing atmosphere of urgency he made a mistake in deliberately taking his time with Aircraft Kh. He wanted to be certain he had got it right. In summer 1939 he made the final major design change, reducing the wing area from 17.9 to 17.44sq m (187.7sq ft), having come to the conclusion that increased wing loading could mean higher performance without significant penalty in manoeuvrability. He was aware that the wing area of the Bf 109E was only 16.4sq m.

In October 1939 Polikarpov was sent to Germany as a member of an aviation delegation, following the signature in late August of the German/Soviet nonaggression pact which cleared the way for Hitler's invasion of Poland. In his absence a special commission was appointed to investigate his fighter designs. At this time Yakovlev's first single-engined fighter, the I-26, was almost ready for flight, and was confidently expected to go into production. However, the commission was assured by one of Polikarpov's senior designers, Aleksei S Karev, that Aircraft Kh would be 70km/h (43.5mph) faster than the I-26. This was met with disbelief and suspicion. At this point the director of GAZ No. 1, Pavel A Voronin, saw his chance. Though Polikarpov had been told that the new fighter would be produced at GAZ No. 21, Voronin was naturally expecting to build the prototypes, and with GAZ No. 1's chief engineer Pyotr V Dement'yev he managed to convince the commission that Aircraft Kh really would be much faster than Yakovlev's. After all, it would be about the same size but would have a bigger engine. Everyone knew that, in Stalin's view, speed was all that mattered.

Voronin and Dement'yev impressed the commission, and through them the NKAP, which saw the ideal way to form the new fighter team of bright young men: hand over to them Polikarpov's Aircraft Kh. Within days, later in October 1939, the NKAP authorized Voronin to form the required OKO at GAZ No. 1, the same location as Polikarpov's OKB. It was to be formed by transferring to it two of Polikarpov's principal fighter subsections, KB-2 and KB-3. The new OKO was to be directly under Voronin's control, his place as director of GAZ No. 1 being taken by Dement'yev.

Stalin approved as head of the OKO Artyom Ivanovich Mikoyan, who at once exercised the privileges of a chief constructor. His deputies were Mikhail Iosifovich Gurevich and Vladimir A Romodin. Other team leaders were A G Brunov, D N Kurguzov, Ya I Selyetskiy, N I Adrianov and N Z Matyuk. It was announced that any problems encountered by the new OKO were to be referred directly to the NKAP. On 8 December 1939 the new OKO was formally established, and on 14 December Mikoyan was appointed deputy chief constructor of GAZ No. 1. By this time more than one-third of Polikarpov's design engineers had elected to join the new team or had been transferred to it.

Nothing like this had happened before, and to say it was a slap in the face for Polikarpov is an understatement. The original OKB management had not been consulted, but friction was tempered by fear, because the upstart OKO was obviously politically favoured. One of Polikarpov's lady engineers dared to write to M K Yangel, the Party organizer at GAZ No.

21 at Gor'kiy, where they were engaged in getting the I-180 into production, 'You would not believe what is happening here … you must return to help to save our collective'.

According to historian Vladimir Ivanov, writing in the magazine *Kryl'ya Rodiny*, 'The rumour spread that on his return from Germany Polikarpov would be executed … an unhealthy atmosphere, resembling that which preceded his previous incarceration, began to surround him'. Of course, on his return to his OKB Polikarpov was shocked. He wrote to the NKAP main directorate 'It has to be pointed out that I have not been relieved from the duties of Chief Designer of GAZ No. 1.'

The point has to be made that the new design department took over an almost completed design. Thus, what became the first MiG was really a Polikarpov aircraft. Drawings for the new fighter began to be released to GAZ No. 1 in November 1939, the aircraft shortly afterwards being given the NKAP fighter designation of I-200. In early 1940 it was decided to clear the air by transferring Polikarpov's OKB to GAZ No. 51. When he was asked for his views on the I-200, what could he say? He replied 'Artyom Ivanovich [Mikoyan] is working on it, so let him finish it'. At one point he let slip 'In Germany one can appeal to Goering, but here to whom?' In Stalin's era of terror such a comment could have been more than enough for the speaker suddenly to disappear. Indeed, M M Kaganovich, the head of NKAP to whom Polikarpov *did* appeal in January 1940, was suddenly relieved of his duties and a few days later committed suicide. Polikarpov was extremely fortunate to survive.

Unaffected by the aggravation, the newly formed OKO at GAZ No. 1 made outstandingly rapid progress with the I-200. Initially it worked on two proposed versions, the I-61 with the AM-35A engine and the I-63 with the slightly more powerful AM-37. To have a second string to their bow, it was decided to form a subsection to work on an armoured attack aircraft, TSh or Type 65. This was soon abandoned, and effort was concentrated entirely on the Kh fighter, and eventually it was reluctantly accepted that this would have to have the AM-35A engine.

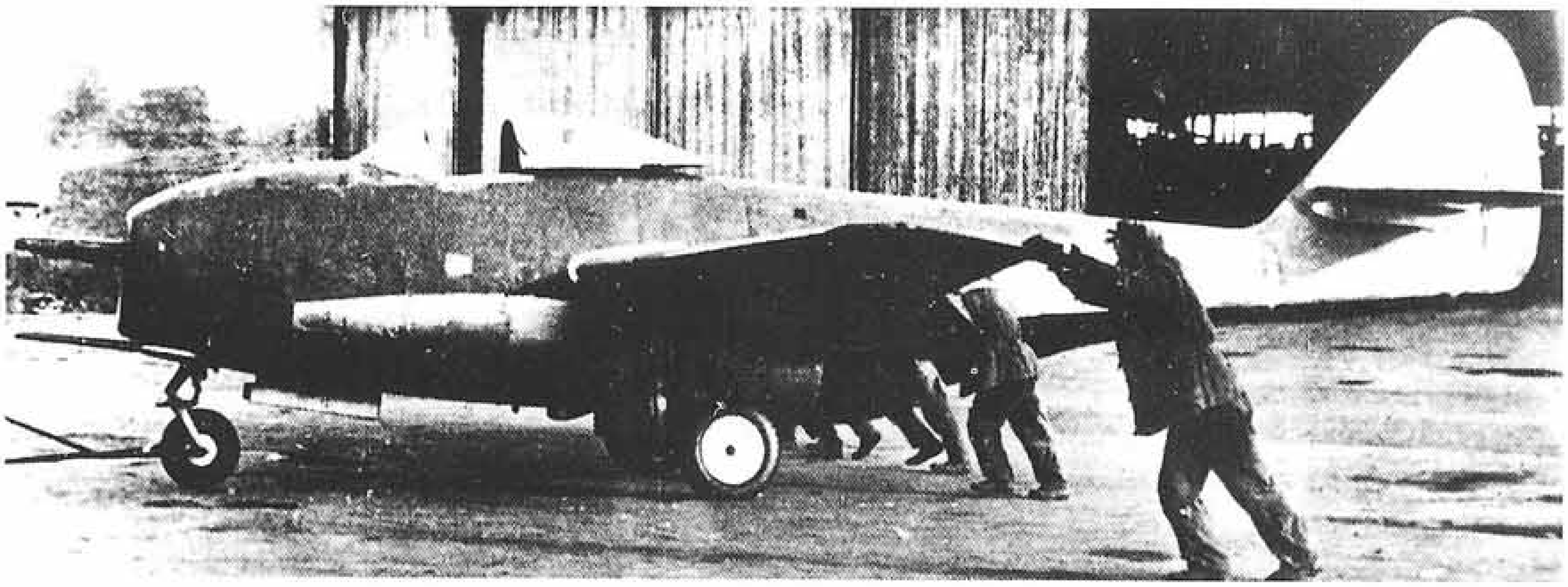
As explained in the second entry in this book, despite various minor design changes, the prototype began to be assembled in January 1940 and made its first flight only 85 days later on 5 April. A month earlier, on 15 March, the OKO was elevated to the status of a full OKB, Polikarpov having been removed to GAZ No. 51. Mikoyan was naturally appointed chief constructor, Gurevich being his deputy. At this time the old aircraft designations based on function, such as I-200 (from *istrebitel'*, fighter) were being replaced by new designations derived from the name of the chief constructor. Thus, when in December 1940 the I-200 was selected for production, its Service designation was MiG-1, from Mikoyan and his deputy Gurevich.

A I Mikoyan had been born on 5 August 1905 in Sanain (now Tumanyan), a remote village in Armenia. The second son of a carpenter, he was actually christened Anushavan Ivanovich, but at an early age he acquired the nickname Artyom, and this gradually took over as his official given name. In 1918 he succeeded in gaining admission to high school in Tiflis (Tbilisi), Georgia. He worked as a mechanic in factories in Rostov and Moscow before serving in the Red Army in 1928–30. In 1931 he entered the VVA (Air Force Academy), where in addition to intensive classroom studies he became both a pilot and a parachutist. As part of his course he was sent to Kharkov to work with the OKB of D P Grigorovich. In 1936, with two friends, he built and flew *Oktyabryonok*, a successful ultralight named for the children aged 7–10 preparing to become Young Pioneers.

Having graduated from the academy in 1937 with the highest possible diploma, he was appointed VVS inspector (in other words, the representative of the customer) at GAZ No. 1, which was building the Polikarpov I-15bis biplane fighter. His ability was evident from the outset, and he was soon additionally made permanent representative at Polikarpov's OKB. By 1938 Mikoyan had become involved in the design and development process, particularly that of the I-153.

Mikoyan's selection as head of the new OKO was unquestionably based on merit, and as chief constructor of the subsequent MiG OKB his record speaks for itself. Nevertheless, it is pertinent to note that his elder brother Anastas had been a leading Bolshevik and subsequently a rising force in the Soviet Union. He was elected to the Politburo in 1935, and in 1946 was appointed deputy premier and vice-chairman of the Council of Ministers. Some observers have speculated that, had this not been the case, the MiG OKB's failure to produce important aircraft during the Great Patriotic War would have resulted in its closure. On the other hand, Stalin's terror was entirely aimed at eliminating possible rivals, and when he was told that A I

Gurevich and Mikoyan just after the war. (OKB)



Pushing out the first production MiG-9 from OKB-155. (OKB)

Mikoyan was the choice to head the OKO he snarled and exclaimed 'What – Anastas's brother?'

Contributor of the G in MiG, Mikhail Iosifovich Gurevich was born on 12 January 1892. His father worked in a distillery in Rubanshchin, near Kursk, Ukraine. He studied advanced maths at the University of Kharkov, but was expelled for revolutionary activity, so in 1913 he resumed his studies at the University of Montpellier. After the 1917 Revolution he returned to Kharkov, where he organized a faculty of aviation. In 1928 he joined the KB of P A Richard as engineer-constructor. In 1931 this KB was closed, and Richard returned to his native France. Gurevich moved to the Central Aero and Hydrodynamic Institute, and from there to the OKB of S A Kochyerigin, becoming his deputy and leader of the brigade designing the TSh-3 attack monoplane.

His quiet diplomatic nature and command of English resulted in him accompanying B P Lisunov to the Douglas company to assist the licence agreement for the DC-3. He then helped get this aircraft into production at GAZ No. 84. This brought him into contact with Polikarpov, whom he joined in late 1938 as head of project studies. He soon became friendly with Mikoyan, and their very different characters dovetailed perfectly. Thus, when Mikoyan was offered the top job in the new OKO he said 'Provided Gurevich can be my deputy'.

As noted later, the I-200 naturally had exceptional performance, because it had a massive engine in a small airframe. In May 1940 it may have become the first fighter to exceed 644km/h (400mph) in level flight. On the other hand it was a demanding aircraft, even dangerous to an inexperienced pilot. Despite this, it was put into high-rate production as the MiG-1, later improved as the MiG-3, with GAZ No. 1 reaching an output of twenty-five a day by summer 1941. Thus, when Germany invaded the Soviet Union on 22 June 1941 over one-third of the fighters were MiGs (most of the others were obsolete).

In October 1941 all aircraft design and production centres in the Moscow area were urgently evacuated to the East. The difficulties and upheaval can barely be imagined, especially as beyond Moscow roads became mere tracks of mud, which froze quickly. GAZ No. 1, and the associated MiG OKB, were relocated at Kuibyshev, on the Volga. Here production took some time to pick up again. In any case, in December 1941 Stalin ordered that the Ilyushin Il-2 Sturmovik should have priority over the MiG-3, and that the engine factory should stop production of the MiG-3 engine and concentrate entirely on the Il-2's engine.

Thus, the last MiG-3 came off the assembly line at the beginning of 1942. In March 1942 GAZ No. 1 and the OKB returned to Moscow. The factory reoccupied its Khodynka site, but a Kremlin decree of 16 March reorganized the OKB on the site of GAZ No. 155. This was a wasteland on the *Leningradskoye Shossé* (Leningrad Highway). Dilapidated barrack huts and other buildings were renovated, and new buildings erected. For nearly fifty years the MiG team were called OKB-155.

For the rest of the Great Patriotic War the MiG designers produced one superb fighter prototype after another, but the nearest they got to a production order was a preseries of ten of one type which did very well in combat but still failed to dislodge the established Lavochkins and Yakovlevs. Immediately after the war a small series of sixteen MiG-13 fighters, unique 'piston-engined jet aircraft', was built for naval aviation.

In stark contrast to Western leaders, Stalin professed to know – a very different thing from actually knowing – all about the design of every kind of war weapon, particularly fighter aircraft. This could be dangerous, and in extreme cases could cost a designer his life. In early 1944 he berated the established fighter designers for not having produced jet aircraft, such as those that existed in Germany, Britain and the United States. Mikoyan and Sukhoi were both told to use two German turbojets in an otherwise all-Russian fighter. Sukhoi copied the layout of the Me 262 (to incur the scorn of Yakovlev), but Mikoyan put the engines close together in the bottom of the fuselage.

On 24 April 1946 the first MiG-9 prototype was parked beside the first small single-jet Yak-15 at the LII Flight Research Institute, named for Zhukovskiy. A coin was tossed and Mikoyan won, as a result of which 'Lyosha' Grinchik made the first jet flight in the Soviet Union. At that time the MiG bureau was very much one of the second rank, and nothing like as famous as Yakovlev and Lavochkin. But 24 April has ever since been commemorated as a very important day for Russian aviation, and on that day in 1996 eighteen veteran test pilots gathered beside a replica of the first prototype MiG-9 (Aircraft F-1), at the Monino museum to celebrate the 50th anniversary. They included Mark Gallai, who took over MiG-9 testing after Grinchik had been killed in the F-1 prototype.

Considering its low-powered German engines, the MiG-9 did well, and it at last brought the MiG OKB a real production order. But, in incredible contrast to the British government, Stalin saw that the USSR was engaged in a technological race. He was determined to build jets as good as anything in the West – and nuclear weapons as well. In March 1946, before any Soviet jet had flown, he again called fighter designers to the Kremlin and told them to produce a fighter able to operate from unpaved strips, fly for one hour at Mach numbers up to 0.9 and manoeuvre well at high altitudes.

While British designers received no hint that there might be any urgency, so that 430 American-designed Sabres had to be purchased to give the RAF something resembling a modern fighter, the Labour government thought they would curry favour with their 'comrades' in Moscow by sending them twenty-five examples of the world's most powerful turbojet, the Rolls-Royce Nene. (No production Nenes were delivered to a British factory for a further four years.) At a stroke, this removed the biggest obstacle facing the MiG designers, and the result was Aircraft S, first flown on 30 December 1947.

The MiG designers had produced an absolutely classic aircraft which simply demolished the competition. With the Service designation MiG-15, it was built by the thousand, shocked the Western Allies who encountered it over Korea (at a time when the RAF had nothing in the same class) and put the MiG OKB in the position of fighter pre-eminence previously enjoyed by Yakovlev and Lavochkin.

For the next forty years the sheer ability and pace of the MiG design bureau kept it in this dominant position. Lavochkin faded, and Yakovlev and Sukhoi picked around the edges with radar-equipped all-weather interceptors for the IA-PVO (Fighters of the Air Defence Forces). The massive orders for fighter and attack aircraft for Frontal (tactical) Aviation were almost a MiG monopoly.

In 1947 Gurevich was placed in charge of a new OKB department to develop cruise missiles to be launched from large bombers. This story is related here for the first time. In 1957 he was appointed chief constructor, but his health was rapidly declining. He was forced to relinquish a top position in the challenging MiG-25 programme, and he retired in 1964 – though he outlived Mikoyan, surviving until 1976.

Mikoyan reached the top rank of General Constructor on 20 December 1956, but on 27 May 1969 he suffered a stroke which incapacitated him completely. His first deputy, Rostislav Apollosovich Belyakov, became *de facto* general constructor, but did not actually receive the title until early 1971, a few weeks after Mikoyan's death on 9 December 1970.

In the early postwar period a combined total of appreciably more than 20,000 examples had been built of the MiG-15 and MiG-17. These were followed by the supersonic MiG-19 and Mach-2 MiG-21, over 10,000 of which were built in the Soviet Union for an all-time record fifty-six customer air forces. During the next three decades the MiG OKB continued to prosper, with several factories

One of the MiG flight-control laboratories in the 1980s. (OKB)

The top team in the 1980s, front row (from left) Mikhail R Waldenburg, Gregoryi Sedov, Rostislav A Belyakov, Nikolai Matyuk and Anatoliy A Belosvet. (OKB)

building more MiG fighters (very nearly 20,000 since 1960, excluding licence-production) than any other fighters elsewhere. Major types included the swing-wing MiG-23 and -27, the Mach-3 MiG-25 and the brilliant MiG-29 family.

In 1990 the OKB was renamed the A I Mikoyan ANPK (Aviation Scientific-Industrial Complex), with the associated MMZ (Moscow Machine Factory) also named for Mikoyan. In 1995 the government approved the merger of the ANPK with MAPO (Moscow Aircraft Scientific Production Organization) to form a fully capable design and production organization which includes the old Khodynka factory. Products include not only the aircraft featured in this book but also aircraft designed by Aeroprogress, Ilyushin and MAI. Since it was formed MAPO-MiG has invested over 2,300 billion roubles not only to produce aircraft but also to train customers and to offer worldwide support.

In some 1997 documents MiG has become MIG, from Military Industrial Group, while to confuse the issue further many publications call the enterprise MIC-MAPO, MIC standing for Military Industrial Complex. Chairman and chief executive officer is Aleksander N Bezroukov, who unlike most Russian leaders was only 33 years old in 1997. Chief designer is Valerii Novikov, and general designer is Mikhail Romanovich Waldenburg, who had been deputy general constructor of the original OKB and chief designer of the MiG-29.

Although every care has been taken to ensure accuracy in this work there are a few instances where precise figures in the data cannot be confirmed. In such cases the lowest and highest reported figures are both shown linked by a dash. V B Shavrov, quoted as the source for some figures, was a renowned aircraft designer and historian.

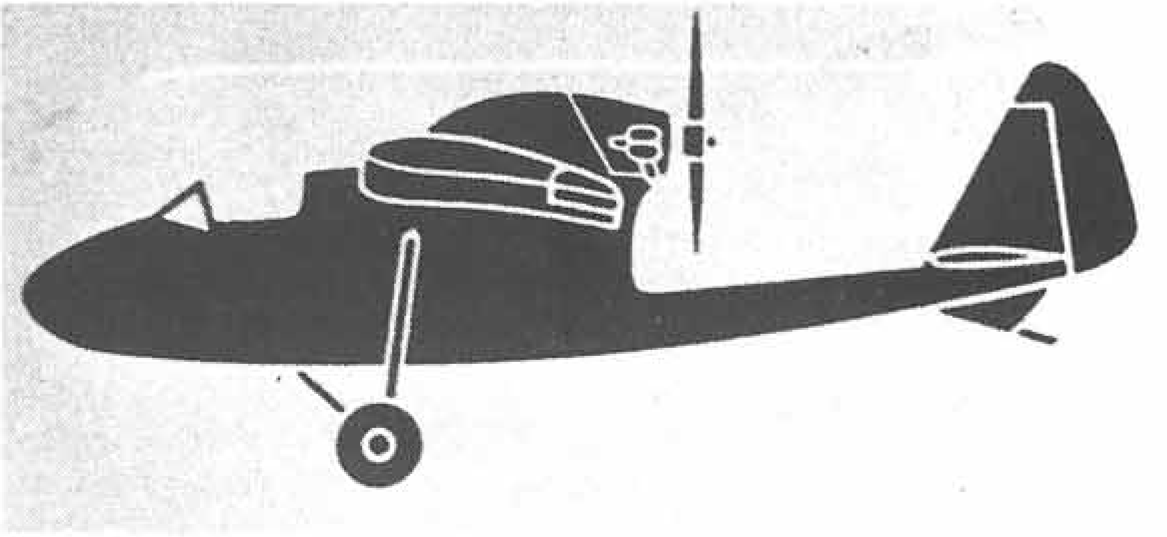
General Designer Anatoliy A Belosvet (right) with Marshal Pyotr Deinekin, C-in-C of the air force. (photograph by Yefim Gordon)

The Aircraft

Oktyabryonok

Though not strictly a MiG design, this ultralight sports aircraft was designed by A I Mikoyan, assisted by K Samarin and also later by N A Pavlov. All three were students at the VVA (Air Force Academy named for Zhukovskiy), and creating this simple aircraft was their diploma project on graduation in 1936. The name is that – in essence, 'Born of the October Revolution' – given to children aged between 7 and 10 preparing to enter the Young Pioneers.

An exceedingly neat design, it had the single-seat cockpit in the nose of a short fuselage nacelle, with a main landing gear on each side comprising a pivoted V frame and near-vertical shock strut. Behind the cockpit was a pylon to which the wing was attached, above which on the centreline were the streamlined fuel tank and 25hp Labur two-cylinder two-stroke engine driving a wooden pusher propeller. This American engine was stripped and refurbished by two more VVA students, V A Romodin and V Tertsiyev.



Oktyabryonok *drawing, but lacking detail.*

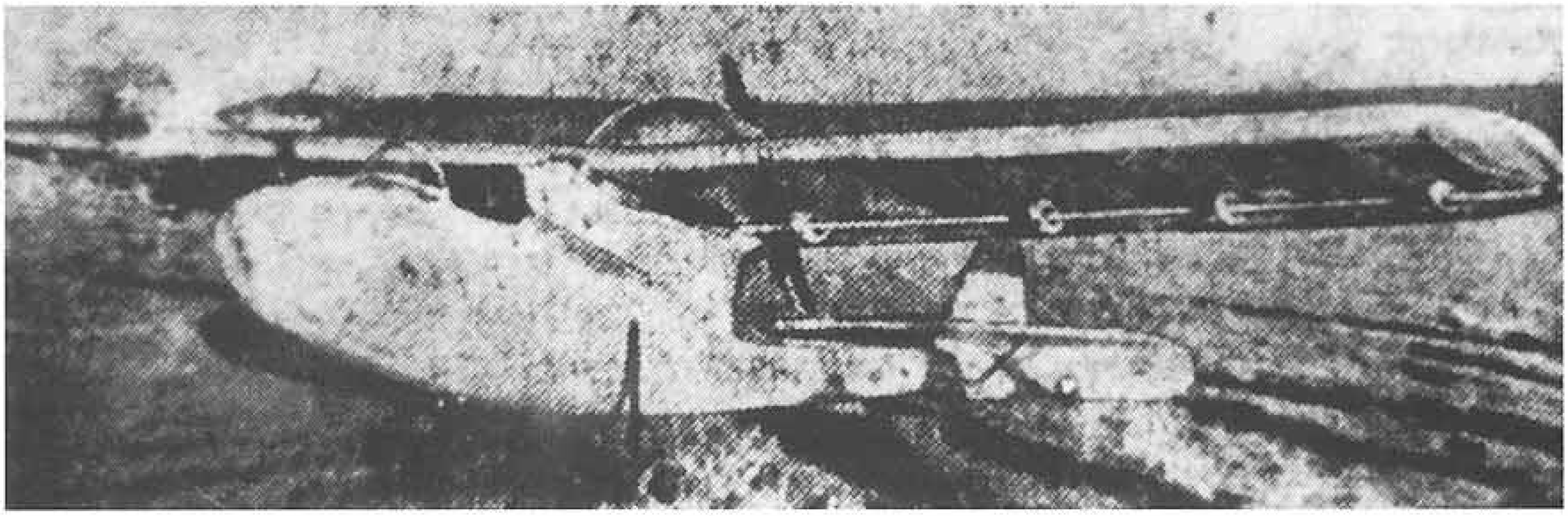
The wing had dihedral but was untapered. Its entire trailing edge comprised slotted flaps and ailerons. To leave room for the propeller, the nacelle terminated at the trailing edge of the pylon, the tail being carried on a slender boom. The tail was simple, but an unusual feature was that, while the tailplane was strut-braced, the wing was a pure cantilever. The entire airframe was of wood, with metal angles and plates at major joints, the covering being veneer over the nacelle and wing leading edge and fabric elsewhere, except for the tail boom which had a central keel and multiwrapped veneer skin.

Actual construction was possible after the project had received a favourable assessment by the VVA faculty, followed by exceptionally enthusiastic approval by the Aviakhim technical commission. The latter even suggested that *Oktyabryonok* should be put into production, at the remarkably low estimated price of only 5,000 roubles. V V Bubnov was appointed test pilot, and he made the maiden flight in mid-November 1936, praising the aircraft without reservation. Unfortunately, the tired engine suffered major failure on the fourth flight, and though a new engine could have been fitted the entire enterprise was abandoned because Mikoyan and his helpers were all busy with their professional careers.

Span 8m (26ft 3in); length 6.2m (20ft 4in); wing area 11.4sq m (123sq ft).

Weight empty 150kg (331lb); fuel/oil 20kg (44lb); weight loaded 264kg (582lb).

Maximum speed 126km/h (78mph) at sea level, 124km/h (77mph) at 2,000m (6,560ft); service ceiling (estimated) 3,000m (9,843ft); range estimated 210km (130 miles); takeoff run 85m (279ft); landing speed 45km/h (28mph); landing run 50m (164ft).



Oktyabryonok, *the only known photograph.* (OKB)

I-200

Originally known in the Polikarpov OKB as Aircraft Kh (Russian X), this was intended to be the optimum fighter powered by the AM-37 developed by the engine KB of A A Mikulin. Though a large and heavy twelve-cylinder liquid-cooled engine, it was judged that this would enable the highest possible maximum speed to be reached, especially at high altitude. Polikarpov saw his main task as fitting it into the smallest possible airframe. Indeed, apart from having to make provision for armament, the overall design resembled that of a pure racing aircraft.

From the outset, although Polikarpov had wished to make the aircraft all-metal, with stressed-skin used wherever possible, it was obvious that supplies of duralumin would be inadequate. Accordingly, he had to adopt traditional mixed construction, with the centre fuselage welded from steel tube and the rear fuselage and outer wings made of wood.

During the detailed engineering phase in the second half of 1939 the design was further compromised by having to accept the previous-generation AM-35A engine. This differed only in detail from the AM-37, which in 1939 was only in the early stages of running on the testbed, but it was slightly less powerful. The engine cowling, which in effect formed the entire forward fuselage, was twice modified to reduce drag and match it more neatly to the shape of the engine. The exhaust system was modified with 'siamesed' (twinned) pipes, and the oil cooler was moved outboard on the left of the crankcase inside a projecting tunnel fairing, with the airflow control flap moved from the exit to the inlet. To improve stability the rear fuselage was lengthened, and the fin and rudder were slightly enlarged. On 8 December 1939 the new OKO took the aircraft over, with the official designation I-200.

The structural basis was the centre fuselage. This was quite short, extending from forwards-sloping front members bolted to the top of the main spar to backwards-sloping rear members parallel to and immediately behind the back of the seat. This structure was a truss welded from seamless oval-section tubes of 30KhGSA (stainless steel) with an ultimate tensile strength of 110 kg/sq mm. The four chief longitudinal members were 40 × 36mm (1.575 × 1.417in), other members being 30 × 27mm or 25 × 22mm. Two longitudinal tubes on top at the front carried bosses for mounting the guns. This section was covered by twelve light-alloy panels secured by quick-release Dzus fasteners to give speedy access to the interior. Two steel forgings welded under the front of the centre fuselage provided joints to the wing centre-section main spar, with four 6mm steel bolts 60mm apart. Two more two-bolt pads sat on the rear spar.

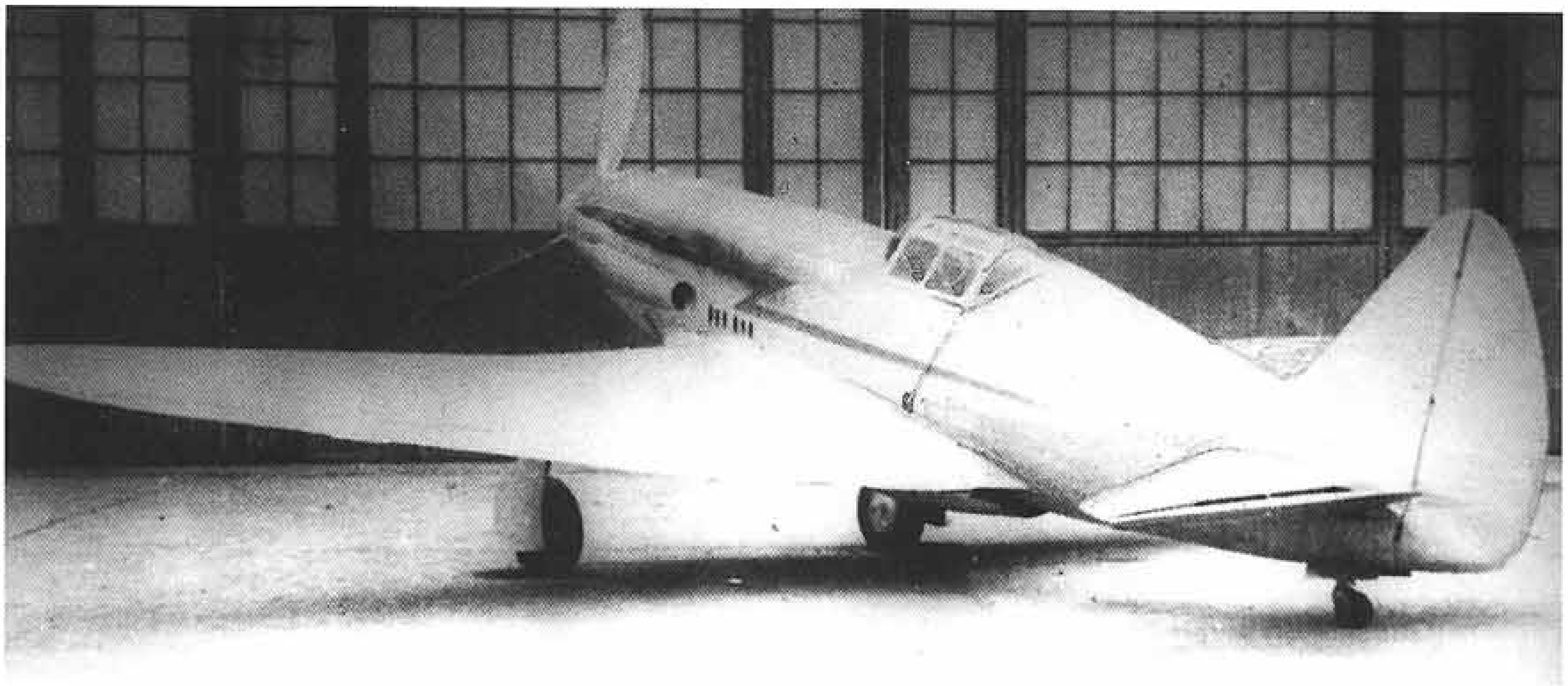
At the back the four main longerons ended in machined forgings of S-20A steel for bolted joints to the corresponding longerons in the rear fuselage. This was made integral with the fin, and was a semimonocoque structure built entirely of wood. Apart from the four main pine longerons there were multiple stringers and nine transverse ring frames glued from multiwrapped pine strips. The last three frames were extended upwards to form fin spars carrying seven ribs. The skin was bakelite-ply, comprising five layers of 0.5mm *shpon* (birch veneer), each being built up from narrow diagonal strips wrapped to the correct shape over the former before having the next bonded by mitkal/nitric glue (and temporarily pinned) over it. The completed shell was then fitted over the underlying structure and glued in place inside surrounding steel jigs with closely spaced bolts (screw presses) screwed down by hand to force the skin inwards on to the members beneath. When set, the inside and outside were each given a layer of varnished calico.

The wing was of simple Clark YH section, with a root thickness/chord ratio of 14 per cent. It tapered sharply from the root, so that, as the centre section had a horizontal underside, the upper surface had slight anhedral. The centre section had a span of 2.8m (approximately 9ft 2¼in), and was based on a main spar at 45 per cent chord. This spar had a web comprising two D16 light alloy sheets each 2mm thick stiffened by riveted vertical angles, each with upper and lower L-booms of machined heat-treated 20KhGSA terminating at forged fork joints to the outer wing.

This spar was the only structural member extending across the centreline. Lighter front and rear spars extended only between the plate ribs at the root and tip of the centre section on each side. Each root rib was extended forwards to carry a forged anchor for the lower engine mount. The port and starboard centre wings were each completed by three outline ribs rolled from angle, and seven spanwise stringers over the upper surface supporting flush-riveted skin. The underside comprised a short section wrapped round the leading edge, the retracted landing gear, a large removable stress-bearing stiffened panel under the fuel tank secured by 6mm countersunk bolts at 60mm spacing screwed into nuts fixed in the wing structure, and the inboard flap.

Each outer panel continued the sharp taper to a pointed tip, where the thickness/chord ratio was reduced to 8 per cent, and was set at zero incidence but a dihedral angle of 5°. As in the centre section, virtually all the bending strength resided in the single main spar. This comprised a beam which at the root was made up of seven 4mm webs of birch ply, with the 14 or 15mm spaces between them filled completely by *delta-drevesina*, compressed and densified wood. These fillers soon tapered into upper and lower booms, while the number of ply webs reduced to six and finally to five. Thus, the effective width of the spar tapered from 115mm at the root to 75mm near the tip. The adhesive was of the resin cement type. Simpler pine/plywood spars lined up with the front and rear spars of the centre section, each attached by a single horizontal bolt, but the crucial joint at the main spar had a major fitting of laminated steel held by upper and lower high-tensile bolts each of 12mm (0.472in) diameter.

The outer-wing ribs were wooden. Each had a peripheral member and vertical stiffeners, with a ply sheet web on both sides of Ribs 1 to 5, at the flap/aileron joint, and on the outer side only from Rib 6 to the tip. Between the main spar and the front and rear spars were added full-span stringers to support the skin. This was bakelite ply, comprising five layers of veneer each from 2.5 to 4mm thick, bonded with casein glue. One panel was wrapped round the leading edge to the front spar, above and below, and



I-200 No. 1. (Yefim Gordon archive)

the rest of the structure was skinned with the grain diagonal, joined along the main spar.

The I-200 was fitted with four sections of Schrenk (split) flap, one on each side of the centre wing and one on each outer panel. Each was a simple sheet of D16 reinforced by riveted channel sections in a pattern on the upper surface. They were driven by the aircraft's pneumatic system to 18° for takeoff and 50° for landing, the actuating cylinder causing a projecting fairing above the wing. Outboard of the flaps were the simple ailerons, made of D16 with a metal nose and AST-100 fabric over the rest. Each comprised an inboard and an outboard half, joined by a two-axis universal joint which also incorporated a lug for the centre bearing on the rear wing spar.

The tailplanes, with an area 18 per cent that of the wing, were the only modern stressed-skin parts, designed entirely by the new OKO. The structure comprised two D16 girder-type spars joined by eleven ribs pressed from sheet, with flanged lightening holes. Each spar was capped by upper and lower doubler strips held by countersunk screws. The skin was then flush-riveted. Each tailplane was attached to the matching girder bridge piece in the fuselage by a three-fork machined forging. These in turn were attached by single bolts to the pairs of fuselage fittings which were each secured by four bolts to the wooden rear fuselage.

The fin, with an area 8.75 per cent that of the wing, was wooden and made integral with the rear fuselage. In contrast, the rudder and each elevator were duralumin structures like the ailerons, with a wrapped-sheet nose and perforated sheet ribs. The latter were braced at midchord by criss-cross D16 tape, and the lower part of the rudder was metal-skinned. Each surface had slightly inset hinges, and a screw-driven trimmer made entirely of AMTs aluminium. The rest of each surface was covered in AST-100 fabric.

The engine was mounted on a cradle of welded 30KhGSA tubing pin-jointed to the forward ends of the upper longerons of the centre fuselage and via diagonal outwards-sloping compression struts to the noses of the wing-root ribs. The AM-35A was a typical member of Mikulin's big V-12 family derived partly from the German BMW VI but with a single-speed supercharger of Allison derivation, a Hispano-Suiza-type rear wheelcase and a 'herringbone' double-helical reduction gear of Rolls-Royce Buzzard type. It had a capacity of 46.7 litres (2,850cu in), or one and three-quarters that of a British Merlin. The takeoff rating was 1,350hp, and the dry weight 830kg (1,830lb). This massive weight was mainly due to the fact that takeoff speed was only 2,050rpm, because the whole family of engines had been intended for heavy bombers, from the M-34 to the TB-7. For the same reason, these engines had no provision for a cannon firing through the hub of the propeller.

Air for the supercharger was rammed in at an oval inlet, with a filter, in each wing root, from where aluminium pipes curved round to the eye of the impeller. The engine reduction-gear drove a VISh-22Ye propeller of 3m (9ft 10⅛in) diameter, with a spinner of magnesium alloy and three light-alloy blades with a constant-speed unit governing a hydraulically actuated pitch range from 24° to 44°. The engine was started by the pneumatic system, with bottle storage at 120–150ata (up to 2,200lb/sq in). Originally traditional Hucks starter dogs were provided on the front of the propeller shaft, but these were soon removed. The exhaust pipes, made of EYa1-TL1 heat-resistant steel, were of the circular ejector type, each serving two adjacent cylinders.

The engine was cooled by an unpressurized 40lit system filled with neat glycol, the wide rectangular radiator being mounted in a shallow duct under the centre wing with a pilot-controlled flap at the rear. The header tank was in the front of the cowling on the left side. Close beside it was the oil tank, above the reduction gear. The oil was cooled by a drum matrix in a duct recessed partly into the left side of the cowling, airflow being controlled by a pilot-operated flap at the inlet. Fuel, usually 87-octane, was housed in three tanks of AMTs aluminium. All the available space inside each centre wing behind the bay for the landing gear was occupied by a tank of 150lit (33gal) capacity. These fed the fuselage tank fitted into the truss framework between the engine and cockpit, with a capacity of 110 litres (24.2gal). This tank contained the filler cap, and a float in a vertical tube serving a dial gauge in the cockpit, and supplied the engine. Total capacity was therefore 410 litres (90.2gal), of which 404 litres were usable.

Main landing-gear track was 2.8m (9ft 2¼in). Each unit was based on a vertical air/oil shock strut made of high-strength (130–150kg/sq mm) 30 KhGSA steel, with the usual filling of glycerine diluted by 30 per cent alcohol. Inflated to 39 atmospheres (573lb/sq in) the maximum stroke was 270mm (10.63in). At its lower end was welded the axle, with two tapered roller bearings to carry the wheel with an internal drum brake and 600 × 180mm tyre. Both the brake and retraction were powered by the pneumatic system, operating at 43–50ata (up to 632lb/sq in) from a storage bottle maintained by the engine-driven compressor at 150ata (2,200lb/sq in).

The jack operated on the top of the leg above the pivot, with positive locks both up and down. The unit retracted straight inwards, the bay being sealed by a door attached to the leg with a D-shaped portion hinged at the bottom to cover the retracted wheel. The main leg door was made in four parts hinged together to allow for variation in length of the leg. The castoring tailwheel had a 170 × 90mm solid rubber tyre, carried in a fork on a strut pivoted to a frame carrying the shock-absorbing cylinder in compression. The whole unit could be unlocked and pulled forwards by cables from the main gears, the retraction bay being closed by two doors.

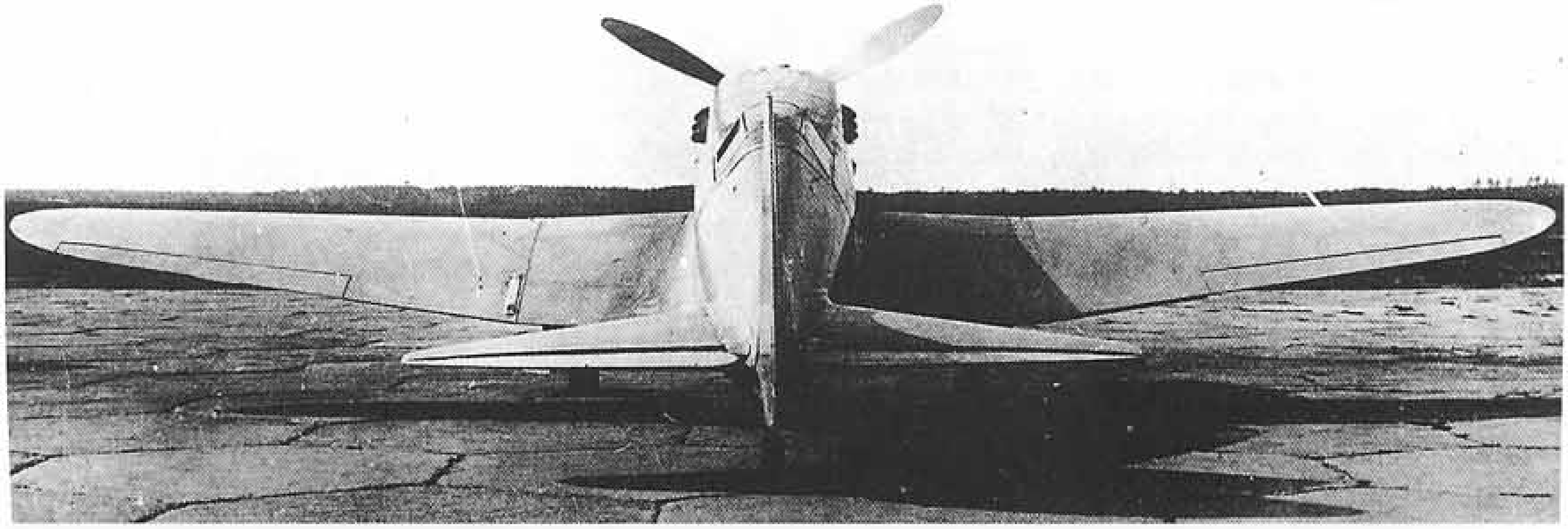
The cockpit was enclosed by a curved windscreen of Plexiglas, a small fixed rear canopy and, between them, a one-piece hood hinged to open up and to the right. The pilot had an aluminium bucket seat with rubber-sprung shock struts and quite complicated linkages for changing position and height. In front was a complete floor pressed from aluminium, which could be removed by undoing three bolts. The parallel-action pedals drove the rudder via cables. The stick-type control column moved the elevators and ailerons entirely by push/pull rods and links, with a damping weight in the elevator circuit.

Full day/night lighting was provided, but the radio racks on the upper deck behind the seat were empty. The main front instrument panel housed, reading from left to right, from the top: altimeter, NI-10 compass repeater, AG-1 horizon, manifold pressure (to 1,600mm), total fuel gauge, ASI (served by a pitot tube mounted well outboard on the starboard wing), turn/slip, VSI (to 30m/sec, 5,906ft/min), engine speed (to 3,000rpm), fuel/oil pressures, outside air pressure and temperature, two pneumatic pressure gauges and the oil temperature. Among the sparse equipment were a GS-350 generator (maximum 30V), mainly for the navigation and cockpit lighting, a 12A-5 h battery and a KPA-3bis oxygen system. Armament (*see* MiG-1) was not fitted to any of the three prototypes.

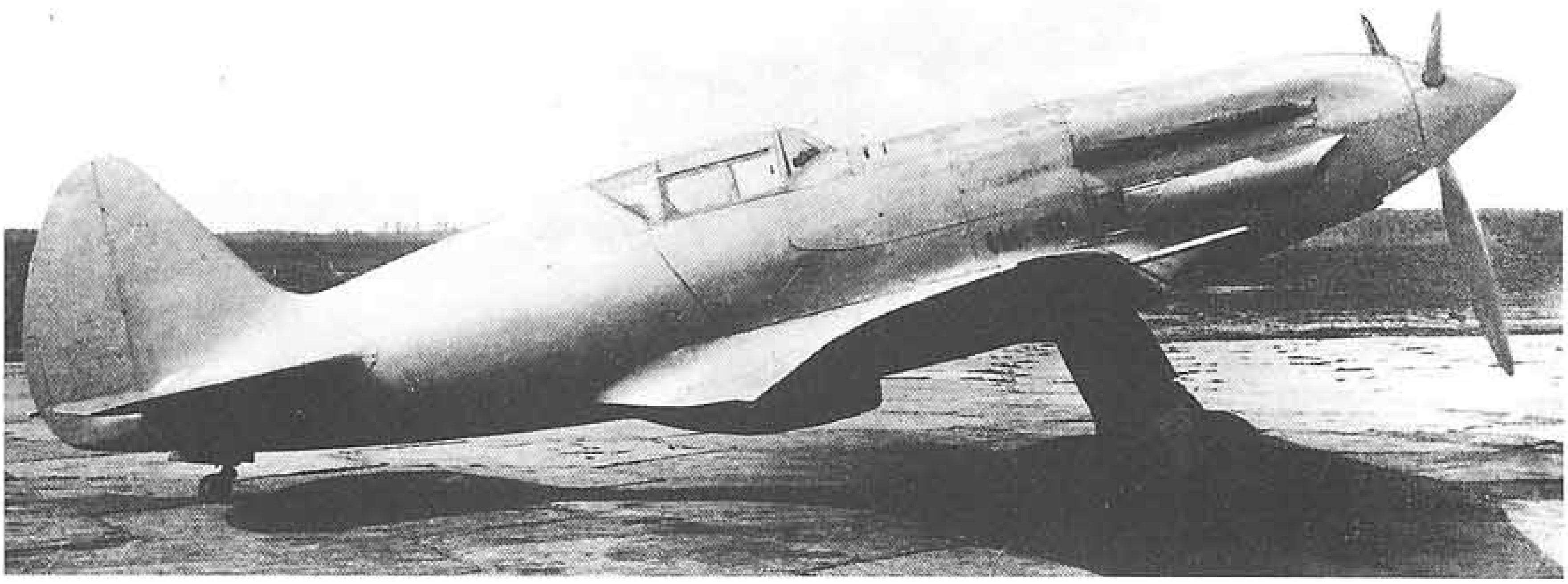
The I-200 No. 01 was constructed under the supervision of Brunov, assisted by Karev. In bare polished metal, it was rolled out on to Khodynka aerodrome on 30 March 1940. The OKB's chief pilot, the veteran Arkadii Nikiforovich Yekatov, had long known that forward view on the ground would be exceptionally poor. Thus, care was needed in the numerous taxi tests, which on 4 April 1940 resulted in the I-200 several times becoming briefly airborne. On the following day, 5 April, the first flight was accomplished. It was at once obvious that handling left a lot to be desired. Takeoff and landing speeds were predictably high, the flight controls were heavy about all three axes, and (contrary to Polikarpov's sanguine belief) the high wing loading made the fighter do its utmost to stall/spin, especially if anything resembling combat manoeuvres were attempted. Longitudinal stability was very poor, and lateral stability at best neutral. Yekatov recognized that a great deal had to be done to turn this aircraft into an acceptable fighter.

In addition, the engine oil and coolant quickly went 'off the clock', even though ambient conditions were still around freezing point. The main radiator duct was improved, and a second oil cooler, identical to the first, was installed on the right side of the cowling, but repeated modifications were needed before temperatures could be stabilized.

On 1 May the new prototype took part in the parade over Red Square, apparently unnoticed by Western air attachés or journalists. I-200 No. 02 joined the test programme on 9 May 1940, the third aircraft flying on 6 June. Yekatov was assisted by M N Yakushin, A I Zhukov and M K Martselyuk. Intensive effort progressively brought these aircraft to a more satis-



I-200 No. 3. (Yefim Gordon archive)



I-200 No. 3. (Yefim Gordon archive)

factory condition. Unlike some aircraft at this time, there was no doubt that the I-200 did have the makings of a quite formidable fighter, but only in the hands of an experienced pilot. On 22 May Yekatov reached a corrected speed of 648.5km/h. Soon afterwards Suprun made a full-throttle run with the No. 02 aircraft at about 7,000m (22,966ft) and reached 651km/h (405mph) while gaining 850m (2,790ft) in height. Impressive as these figures were, they still missed by a wide margin Polikarpov's hopes, mainly because of natural weight growth and the switch to the AM-35A engine.

On 31 May Klim Voroshilov and other military leaders inspected an I-200 with other new prototypes at the Central Airfield. The factory programme was completed on 25 August 1940, 40 hours 49 minutes having been logged in 109 flights. NII-VVS (air force) testing began on 28 August and was completed on 12 September. Leading engineer was P Nikichenko, and the pilots were P M Stefanovskiy, A G Kochetkov, S P Suprun, A I Filin, A I Kabanov, A G Proshakov and A G Kubyshkin. The report by Lt-Gen P V Richagov described the new fighter's performance as 'second to none when compared with foreign fighters'. As noted earlier, by this time similar speeds were being achieved by the British Howker Typhoon and the American XF4U, both of which were less tricky to fly. Mainwheels and brakes were inadequate, nobody liked the hinged canopy, and perhaps the worst feature was the engine, which often failed and had yet to pass its 50hr test. The report, which listed 112 defects, also included the recommendation to fit slats, to increase fuel capacity to attain the design range of 1,000km, and add protective coating to the tanks.

However, despite its dangerous characteristics, the need was judged so urgent that the I-200 was deemed to have passed its acceptance testing, and in October 1940 it was cleared for production as the MiG-1. An initial order for one hundred was placed on GAZ No. 1, which had already set up the production line and necessary jigging.

Span 10.2m (33ft 5⅝in); length 8.155m (26ft 9in); wing area 17.44sq m (187.7sq ft).

Weight empty 2,475kg (5,456lb); fuel 290kg (639lb); oil 28kg (62lb); weight loaded 2,968kg (6,543lb).

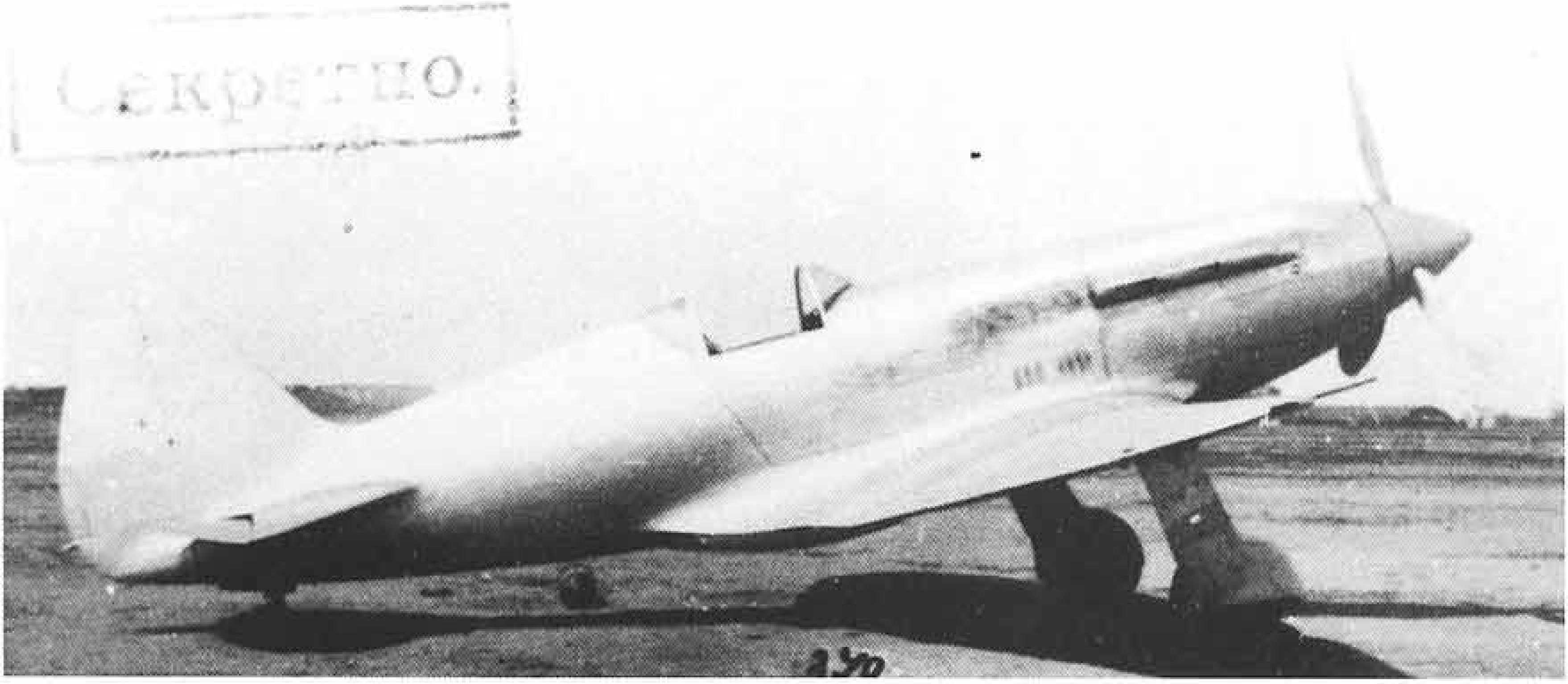
Maximum speed 508km/h (316mph) at sea level, 651km/h (405mph) at 7,000m (22,966ft). Range at cruise rpm 580km (360 miles). No other data available.

MiG-1

Like the original Polikarpov OKB, the new MiG collective had the inestimable advantage of being located at a production plant. Indeed the factory bearing the proud Aviakhim No. 1 could claim to be the premier aviation factory in the entire USSR, and though by 1940 it was no longer the largest, it had produced far more aircraft than any other. Thus, it was perfectly placed to go into large-scale production with the new MiG-1.

As noted, GAZ No. 1 started tooling up for mass production of this fighter in the autumn of 1940, in advance of orders (though it would have been too much of a risk also to order materials and engines). The first NKAP order for one hundred MiG-1 aircraft was probably placed in September 1940. At this time the factory was fast coming to the end of high-rate output of 3,437 I-153 biplane fighters, and eighty-one of Yakovlev's twin-engined BB-22 (Yak-4). It looked forward to building thousands of the exciting new MiG.

Exciting it certainly was, but everyone who flew it recognized that there was plenty of room for improvement. Of course, the first essential was to add armament. Mikulin had not designed the AM-35A to have a cannon firing through the propeller hub, and historian V B Shavrov called this 'the main defect of the MiG fighters'. Standard armament comprised two fast-firing ShKAS machine-guns of 7.62mm calibre mounted above the engine, and one UBS heavy machine-gun of 12.7mm calibre mounted left of centre between them. Each ShKAS had 375 rounds of ammunition housed in a quickly replaceable box mounted diagonally between the fuselage fuel tank and the engine on each side, next to the removable skin panel. The UBS had 300 rounds housed in a vertical box pushed up guide channels from below. The pilot had a standard PBP-1 optical gunsight. In addition, each outer wing was provided with an attachment for a bomb rack tailored to



A production MiG-1, unpainted (print stamped 'secret'). (RART)

either an FAB-50 (110lb) or FAB-100 (220lb) general-purpose bomb.

Most of the airframe, and the AM-35A engine and VISh-22Ye propeller, were unchanged. Of course, all series aircraft had the two oil coolers. Their installation was redesigned with a plain oval inlet, the airflow being controlled by a hinged flap at the exit, positioned either thermostatically or by the pilot. The fuel system was extended to make provision for a 280lit (61.6gal) streamlined auxiliary fuel tank under each outer wing. These were not jettisonable, and they fed direct to the five-way selector and thence to the engine, the pilot switching to the internal tanks when external fuel was exhausted. No photographs have been found showing them installed.

The improved main glycol radiator had a matrix frontal area of 2,300sq cm (356.5sq in), and its duct was extended forwards and improved aerodynamically. The retracted mainwheels were enclosed by small doors hinged under the wing roots, instead of to the bottom of the leg doors. A landing light was installed in the leading edge of the port outer wing just outboard of the junction with the centre section.

It had been intended to fit cockpit armour, but most, if not all, MiG-1 fighters were without it (partly because it was difficult to obtain). On the other hand, they were among the first aircraft in the USSR to have a layer of uncured rubber around the three internal fuel tanks to provide self-sealing of bullet holes. All the series aircraft were fitted with the standard RSI-3 radio, installed on the sloping deck behind the cockpit and served by wire antennas from the fin tip to the radio and to a mast sloping to the right on the starboard side ahead of the windscreen. Many pilots had criticized the canopy of the I-200, and several early series aircraft had the canopy removed. From the ninth aircraft the cockpit was fitted with an improved canopy sliding on rollers along two rails, and thus able to be opened in flight.

The first twenty-five MiG-1s were considered to be a preproduction batch, produced in October 1940. Because of the onset of winter they were sent to the 146th IAP at Evpatoria in the Crimea, under the command of Maj Orlov. The resulting testing was assisted by NII pilot Suprun, engineer Nikichenko and factory engineer Karev.

The one hundred MiG-1s were completed in about thirty days ending on 5 December 1940. So far as is known, all were painted, the usual scheme being dark olive green above and pale grey underneath, with plain red star insignia without borders. In full production the camouflage finish was rough enough to reduce the maximum speed significantly, and the series aircraft also grew considerably in weight.

Deliveries began in January 1941. Some went to training units, starting with the Kachinsk pilot school. The first to reach a front-line regiment were taken on strength in April 1941. It was a profound change from the aircraft previously flown, especially in the case of units which had flown the fabric-covered biplanes. Despite the high power, the swing on takeoff was not dangerous, but the stall/spin tendency, poor longitudinal stability and other challenges were almost as bad as ever. Predictably, the accident rate was high. On 13 March 1941 test pilot Yekatov was killed in flight by uncontained failure of the supercharger impeller.

Dimensions unchanged from I-200.

Weight empty 2,602kg (5,736lb); fuel unchanged, except for provision for underwing tanks, not taken into account in these data; oil 30kg (66lb); weight loaded 3,099kg (6,832lb).

Maximum speed 486km/h (302mph) at sea level, 628km/h (390mph) at 7,200m (23,620ft); climb to 5,000m (16,404ft) 5.9min; service ceiling 12,000m (39,370ft); range with 10 per cent fuel reserve (without underwing tanks) 580km (360 miles); takeoff run 238m (781ft); landing speed 141km/h (88mph); landing run 400m (1,312ft).

MiG-3

While the MiG-1 was being developed, urgent efforts were being made to cure the worst of its shortcomings, it being accepted that most of these modifications would be too late for the initial series aircraft. Accordingly, those that were accepted were introduced from the 101st aircraft, with the changed designation MiG-3 (at this time fighters received only odd designation numbers).

Though the engine was unchanged, it was moved forwards 100mm (3.94in) to shift the centre of gravity. The MiG-1 had always tended to be tail-heavy, resulting in dangerously inadequate static longitudinal stability. The new centre-of-gravity positions were 20.1 per cent MAC (mean aerodynamic chord) with the aircraft empty, and 27.3 per cent fully loaded.

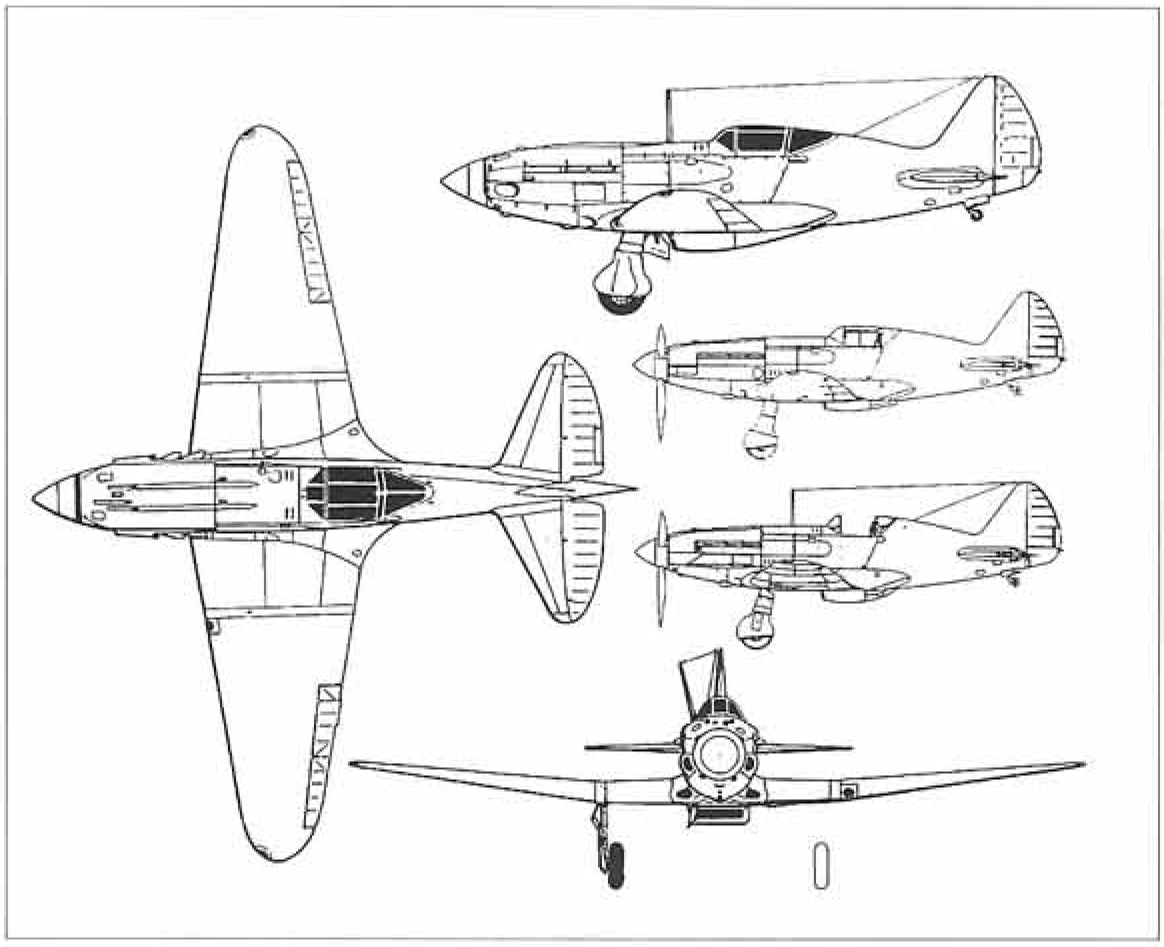
The propeller was changed to the VISh-61Sh, with blades unaltered but with the pitch range increased to 35°. The air intakes to the supercharger were refined in shape, and the powerplant group was further improved by yet another redesign of the main coolant radiator. A new tube-plate matrix radiator block was introduced, in a deeper duct extended aft to a point level with the end of the wing-root fillet, but with the adjustable airflow exit flap immediately behind the matrix. The new radiator inlet was just twice as deep as that of the I-200.

The new radiator installation made it possible to add a riveted AMTs fuel tank under the seat, tapered sharply to fit the fuselage, with a capacity of 250 litres (55gal). It had rubber self-sealing, and a further important addition was that cooled exhaust gas was piped into all four fuel tanks to eliminate oxygen from the space above the fuel. This was common Soviet practice for combat aircraft. At the same time, the provision for external underwing tanks was removed.

Another addition was a supplementary oil tank immediately behind the engine. This was fed from the main tank above the reduction gear, the oil then passing through the pump and engine and back to the main tank via the left and then the right radiators and in-tank filter.

The principal aerodynamic change was to increase dihedral of the outer wings from 5° to 6°, which did bring a further welcome reduction in instability without affecting manoeuvrability. Documents exist extolling the manoeuvrability of the Yak-1 and Yak-7, especially in comparison with that of the MiG-3, whereas historian Shavrov describes the MiG's manoeuvrability above 6,000m (19,685ft) as 'better than that of other fighters'. Time to make a 360° turn was 26–27 seconds, about four seconds longer than for the lighter I-200.

To improve the MiG's ability to operate from front-line airfields the landing gear was slightly strengthened, the main tyres increased in size to 650 × 200mm, and the capacity of the drum brakes increased. The wheel doors were enlarged in consequence, and omitted from some aircraft. Some of the later aircraft had no tailwheel doors, and may have had nonretractable tailwheels.



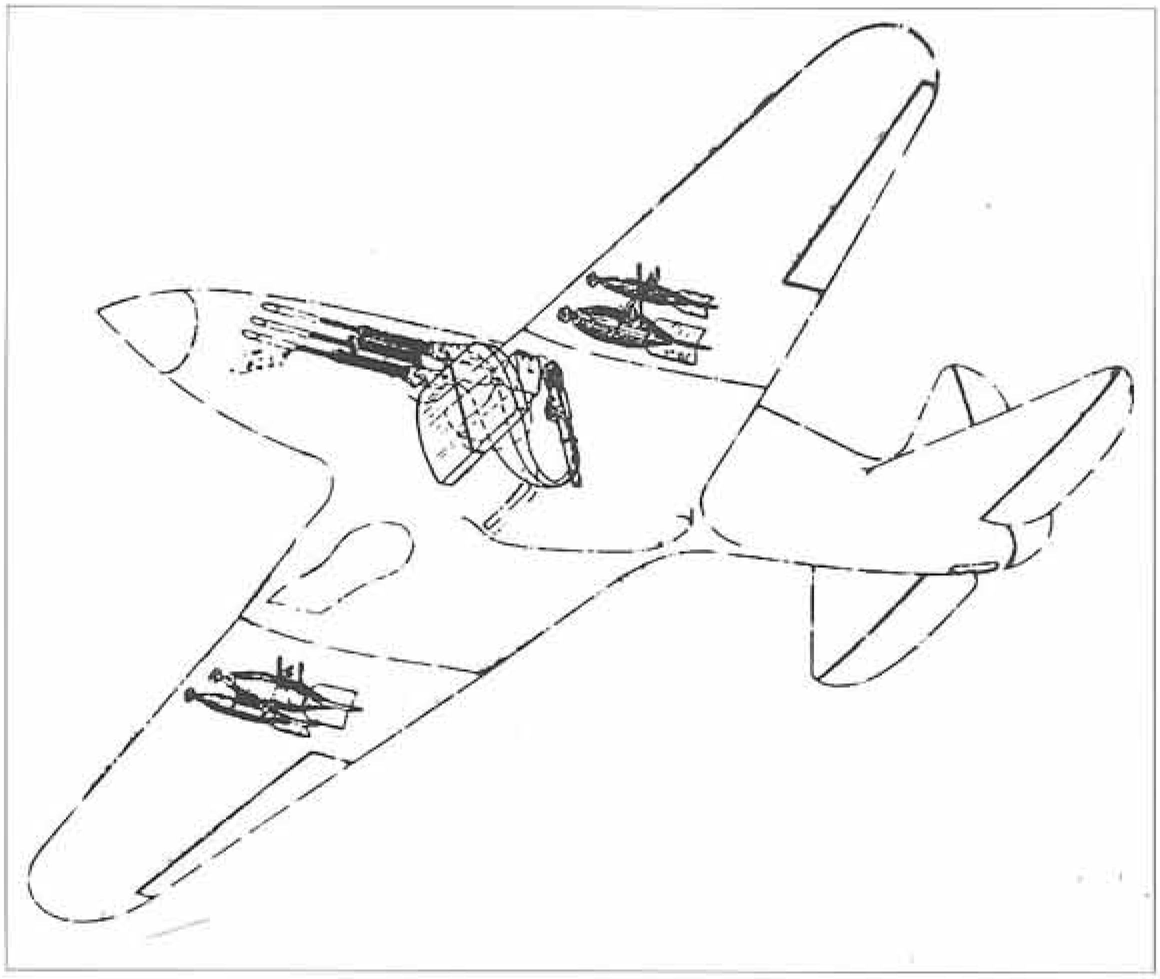
MiG-3 (inset upper, I-200 No. 01 as built; inset lower I-200 No. 03).

The much-criticized cockpit was given an improved layout, including additional instruments, a PBP-1A gunsight and, in later aircraft, the new RSI-4 hf radio. This was installed on a much longer sloping deck behind the seat, the corresponding increase in length of the fixed rear section of canopy being an obvious recognition feature, which also improved the pilot's view to the rear. The long-awaited seat armour was added, initially 8mm thick and later 9mm (0.354in). Among remaining criticisms were that at high speed the canopy could not be opened, and with it shut the cockpit tended to become filled with fuel vapour.

To improve view, and because of the unreliable canopy lock, most pilots left the canopy open at all times. This reduced the range, which was further reduced on the many aircraft not fitted with a mixture control. In their haste to deliver aircraft, the factory also omitted to harmonize the guns, and this was among several tasks which had to be performed at front-line units by special brigades sent from the MiG OKB.

Gun armament was usually as on the MiG-1, but with the ammunition for each ShKAS doubled to 750 rounds. There were many experimental fits, some of which saw active service. In May/June 1941 the factory delivered 821 'five-point' aircraft fitted with a BK gondola under each wing housing a BS gun and 120 rounds. These reduced speed at all altitudes by some 20km/h (12mph). To restore some of the lost speed and manoeuvrability, the capacity of the rear fuselage tank was reduced by 80kg and that of the central tank by 36kg.

Several aircraft had the two ShKAS replaced by a second UBS, on the right side. On at least one aircraft the UBS was replaced by a 20mm ShVAK cannon, and two MiG-3s were actually fitted with two ShVAK in place of the original armament. All were fitted with two hardpoints under each wing for a total of four bombs or other stores up to a maximum of 220kg (485lb). The most common load was two FAB-100 as before, or four FAB-25. In addition, on 180 aircraft, provision was made for launching three RS-82 rockets from under each wing. Other possible loads included two VAP-6M dispensers for HCN or Toxic-B poison gas or two ZAP-6 containers each housing six



MiG-3 armament: UBS plus twin ShKAS, two FAB-100, two FAB-25. (Yefim Gordon archive)

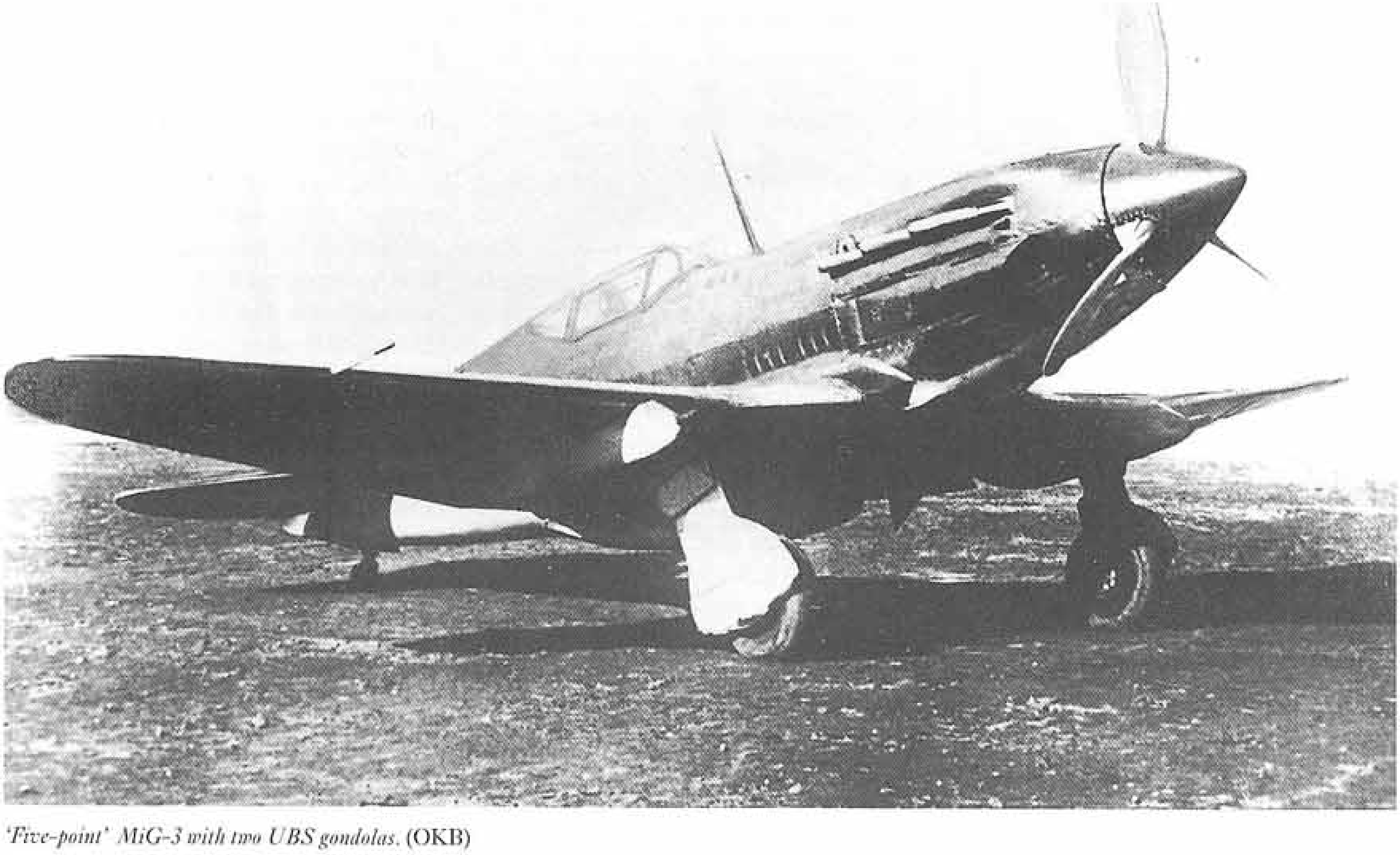
ZAP incendiary bombs. All these loads were tested by the NII-VVS, but only the FAB and RS-82 combinations were used in service.

As noted, the first MiG-3, which was the 101st series aircraft, left GAZ No. 1 on 5 December 1940. By this time the production rate had built up to a level exceeding that of all other Soviet aircraft, and switching from the MiG-1 to the MiG-3 had little effect. Deliveries in January 1941 totalled 140, and by the time Germany attacked the Soviet Union on 22 June 1941, the output had reached levels never attained by any other Soviet fighter. Deliveries totalled 496 in July, 562 in August and 450 in September. On 22 June 1941 no fewer than 37 per cent of the VVS front-line fighters were MiG-1s and MiG-3s. Virtually all the remainder were obsolete, because the Yakovlev and LaGG fighters were only just starting to enter service.

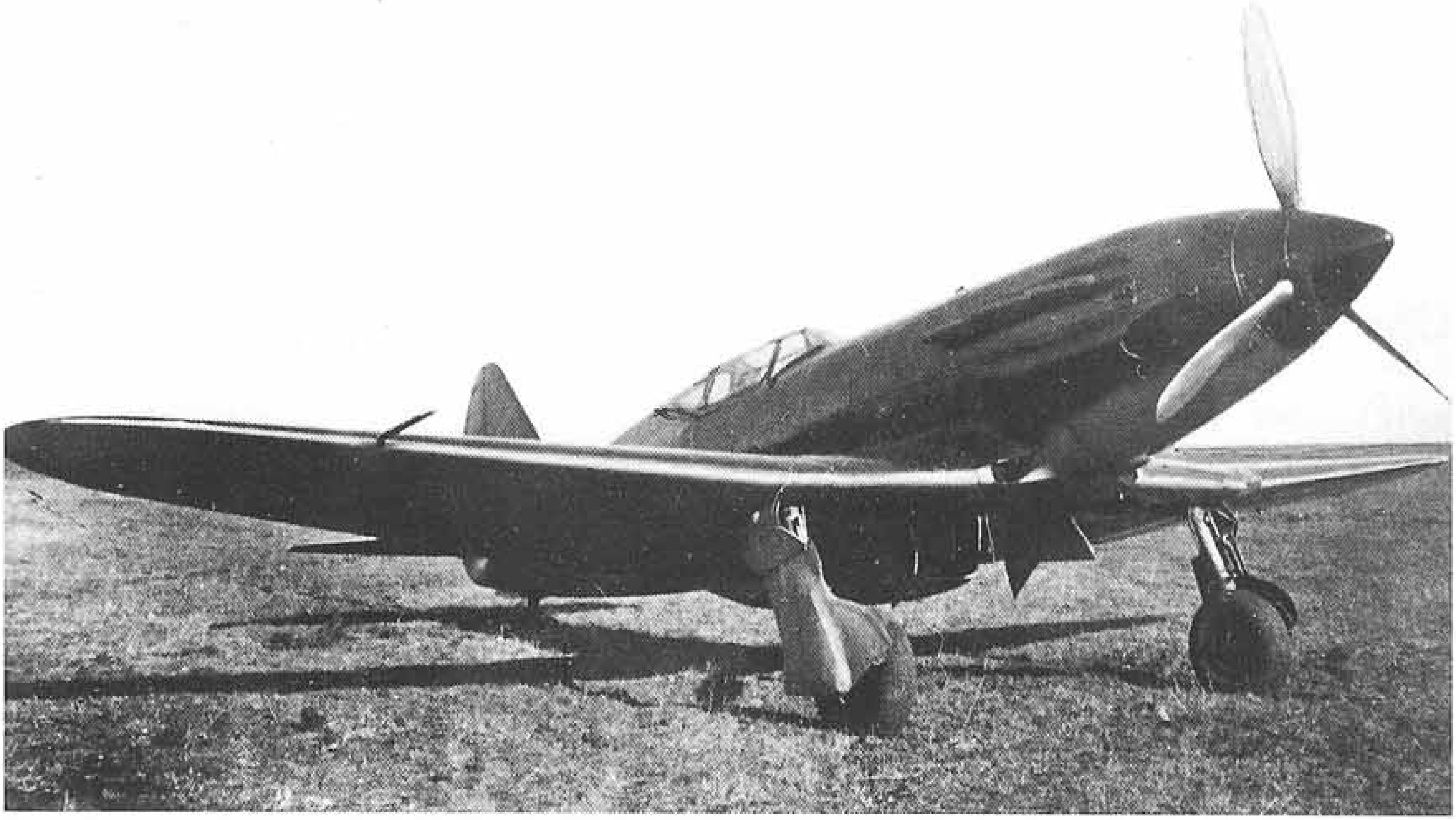
As repeatedly noted, the MiGs were a challenge to an inexperienced pilot, and even to a pilot with long experience of fighters of earlier generations. According to Capt Bondarenko, 'It was difficult to master after the I-16. It seemed less manoeuvrable, and was complex to control. That evoked a doubt in our minds regarding its performance in combat'. The approach speed of 155–160km/h (almost 100mph) was 50 per cent faster than that of the I-153, and the landing run was almost four times as long, combined with nonexistent forward view. According to Shavrov, if the pilot 'lost it' and entered a spin, recovery was not possible. He added 'Pilot fatigue was greater than with other types'.

Perhaps more serious was the endemic unsuitability of the engine. The MiG-1 and MiG-3 never did fully meet the original specification figures, and in range the shortfall was very large. The NII-VVS test centre was accused of having failed to undertake sufficiently rigorous testing.

Despite the problems, the existence of large numbers of these very



'Five-point' MiG-3 with two UBS gondolas. (OKB)



MiG-3 production aircraft No. 04. (Yefim Gordon archive)

fast fighters was so valuable that they were assigned to regiments as near as possible to the only likely enemy, Germany, from Moldavia to the Baltic states. By 1 June 1941 the MiG fighters equipped thirteen complete regiments, with six in the process of conversion. Sadly, more than half the VVS front-line strength, including nearly all the MiGs then delivered, was destroyed on the ground in the first 24 hours of Operation 'Barbarossa'. Maj-Gen S Chernykh of the 9th Mixed Air Division, had repeatedly asked for orders, pointing out rising tension in the summer of 1941 with his fighters strung along the German-occupied Polish border. All he was told was 'Don't give way to provocations'. When his force was almost wiped out on the ground he became an 'enemy of the people' and was shot. It would have been more sensible if Soviet airpower had been deployed further back from the frontier, and dispersed and camouflaged instead of being arrayed in neat lines of closely spaced aircraft at forward airfields.

Though even the early OKB testing included ceiling climbs, the war had started before it was realized that the MiGs were difficult to operate above an altitude of 3,000m (10,000ft). Low fuel-pump pressure, lubrication problems, poor oxygen equipment, bad engine behaviour and stall-spin propensity were among the causes. Pilot-engineer A Kochetkov organized special testing and modification at the 31st IAP at Kovno (Kaunas, Lithuania), one requirement being automatic mixture control. As a result interceptions were possible up to nearly 11,000m (36,000ft).

In the desperate fighting that ensued, nearly all the activity took place at below 5,000m (16,400ft). Here the MiGs were at a disadvantage, inferior to the Bf 109E and also to the Yak-1 and LaGG-3. Losses from accidents and enemy action continued to be severe, and S P Suprun, the senior NII-VVS test pilot, made the startling suggestion that two MiG regiments should be formed from experienced test pilots from factories, design bureaux, the NII-VVS and the VVS. The idea was accepted, and the result was No. 401 Special-Purpose IAP, commanded by Suprun, assigned to Zubovo in the Smolensk sector in the centre of the front, and No. 402, commanded by P M Stefanovskiy, assigned to the Leningrad sector. These regiments did well and continued in action while progressively replacing the test pilots (who were needed elsewhere) with ordinary VVS pilots, who learned fast from the experience.

Though seldom able to operate in its true element, at high altitudes, the MiG-3 did have the great advantage of being outstandingly easy to maintain and repair. Almost the only bad feature was that the tail was integral with the rear fuselage. Another was frequent failure of the landing gear, and in wheels-up landing the radiator and oil coolers were usually damaged. The quality of its manufacture, and resulting interchangeability of parts, was considered to be little short of perfection. Accordingly, the MiG-3 remained in service in many frontal sectors to the end of the war, though its numbers dwindled from attrition. Until 1943 it was certainly the pre-eminent high-altitude and night fighter, and it was also the principal fighter in the defence of Moscow, by day and by night.

By October 1941 the German army had almost reached Moscow. The decision had to be taken to evacuate as many people as possible, and certainly the vital war industries. As related in the introduction, the personnel, machine tools, tooling, materials and aircraft in GAZ No. 1 were all transported to a new site at Kuibyshev. Amazingly, production here rapidly reached the previous level, but it was soon to be brought to a complete stop.

MiG-3 production aircraft No. 04. (Yefim Gordon archive)

In December 1941 Stalin sent what many years later was to become a famous telegram, saying 'The Red Army needs the Il-2 [Sturmovik armoured attack aircraft] like it needs air and bread. Making one a day is an insult. We need Il-2s, not MiGs … This is my last warning.' Almost overnight the engine factory stopped production of the AM-35A in order to deliver the AM-38 for the Il-2 at a higher rate. As a result the MiG-3 line stopped at No. 3,120 on 23 December 1941, the last reaching the VVS the following month.

In March 1942 the threat to Moscow had receded, and the OKB returned to the city. Though it was sent to a completely new site, it was able to complete a further fifty MiG-3 fighters from parts, including engines, that had been hidden away at Khodynka and elsewhere during the evacuation. Thus the total of series aircraft was 100 MiG-1s and 3,170 MiG-3s, all delivered in about a year. Unfortunately for the OKB, no MiG was ever again to be built in large numbers until the jet age.

Dimensions unchanged, except length 8.25m (27ft ⅞in).

Weight empty 2,699kg (5,950lb); fuel 463kg (1,021lb); oil 55kg (110lb); loaded weight (standard) 3,350kg (7,385lb), (with two BK gun gondolas) 3,510kg (7,738lb).

Maximum speed 505km/h (314mph) at sea level, 640km/h (398mph) at 7,800m (25,590ft); climb to 5,000m (16,404ft) 5.7min, to 8,000m (26,250ft) 10.28min; service ceiling 12,000m (39,370ft); range 820km (510 miles); takeoff run (full power, no flap) 234m (768ft); landing speed 144km/h (89.5mph); landing run 400m (1,312ft).

MiG-3 experimental

In addition to the re-engined aircraft described below, one MiG-3 was tested in 1940 with leading-edge slats. At first they extended across the full span of each outer wing, but later they were shortened to lie ahead of the ailerons only. Surprisingly, V B Shavrov, in *History of USSR Aircraft 1938–1950*, gives the impression that this was standard on the MiG-3, and slats are shown in the three-view of the MiG-3 in his otherwise very authoritative book.

MiG-3/AM-37 (MiG-7)

The AM-37 was the engine Polikarpov originally wanted for Aircraft X. The OKB obtained one in May 1941, and as it was identical geometrically to the AM-35A it was installed very quickly. Rated at 1,400hp at 5,000m (16,404ft), the new engine gave improved performance, confirmed in a few flights by OKB pilot A I Zhukov, but no attempt was made at detailed measures as the engine was not in production. In September this aircraft was delivered to the VVS, almost certainly with the AM-37 fitted.

MiG-3/AM-38

This engine was virtually an AM-37 with the supercharger and boost control matched to give maximum output at low altitude. Takeoff power was 1,500hp, and the output peaked at 1,600hp at 2,000m (6,561ft). Again, the geometrical similarity of the AM-38 to the AM-35A made installation straightforward, although for some reason the exhaust pipes were reshaped and the connection to the tank-inerting system removed. Yu K Stankevich began the factory test programme at the beginning of August 1941. Before testing ended on 17 August several OKB and LII-NKAP pilots had flown this aircraft, and detailed measures were taken.

The main problem was engine overheating except in ambient temperatures below about 16°C (61°F). The aircraft was judged superior to the German Bf 109E and other Soviet fighters up to 4,000m (13,120ft), and time for a 360° turn was only 20–21 seconds. No production was possible, because all AM-38 engines were reserved for the Il-2. However, at least eighty damaged MiG fighters were re-engined with repaired AM-38 engines by VVS workshops. Some of these aircraft were modified with two 20mm ShVAK, with 100 rounds each, and sent to PVO (air defence) regiments. The reduced weights are not explained.

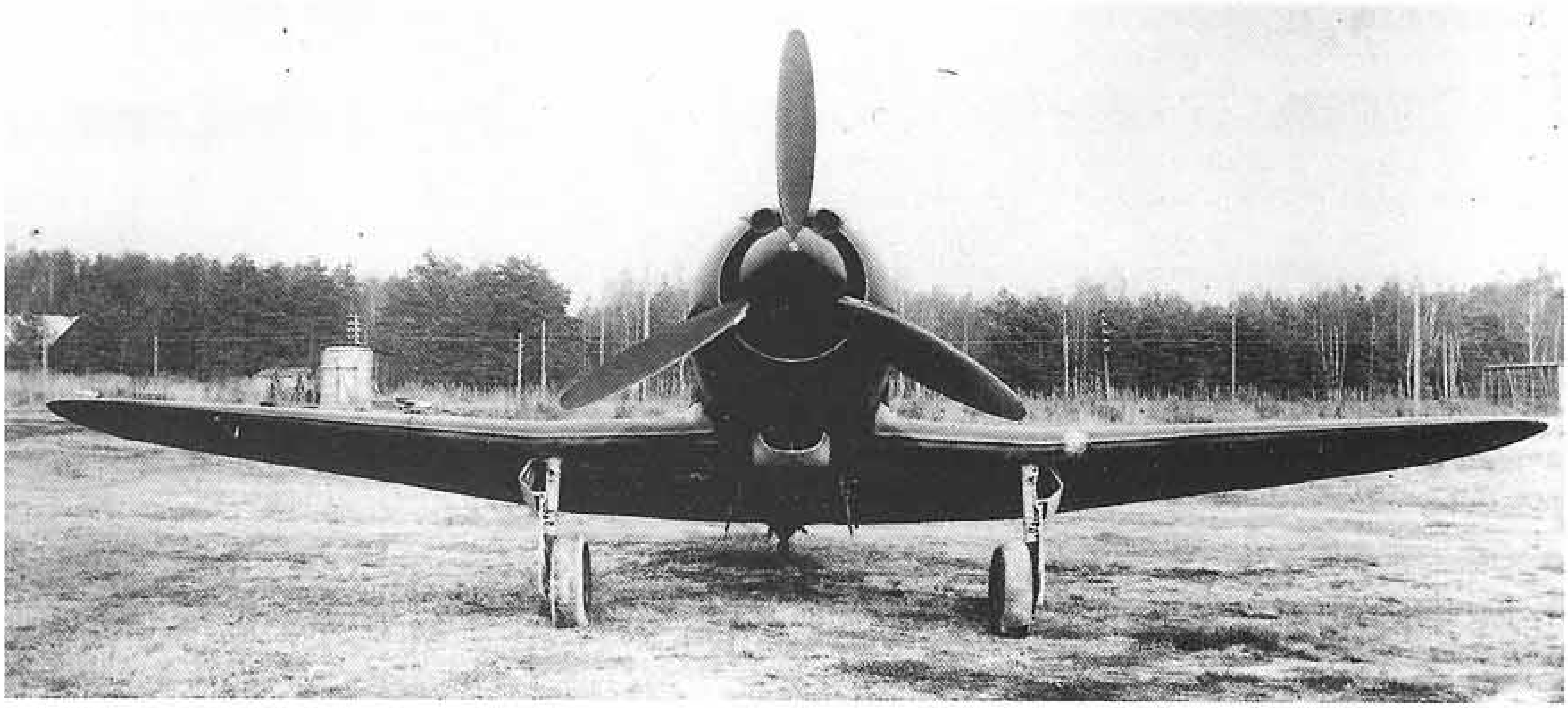
Dimensions unchanged.

Weight empty 2,582kg (5,692lb); fuel 463kg (1,021lb); oil 45kg (99lb); weight loaded 3,225kg (7,110lb).

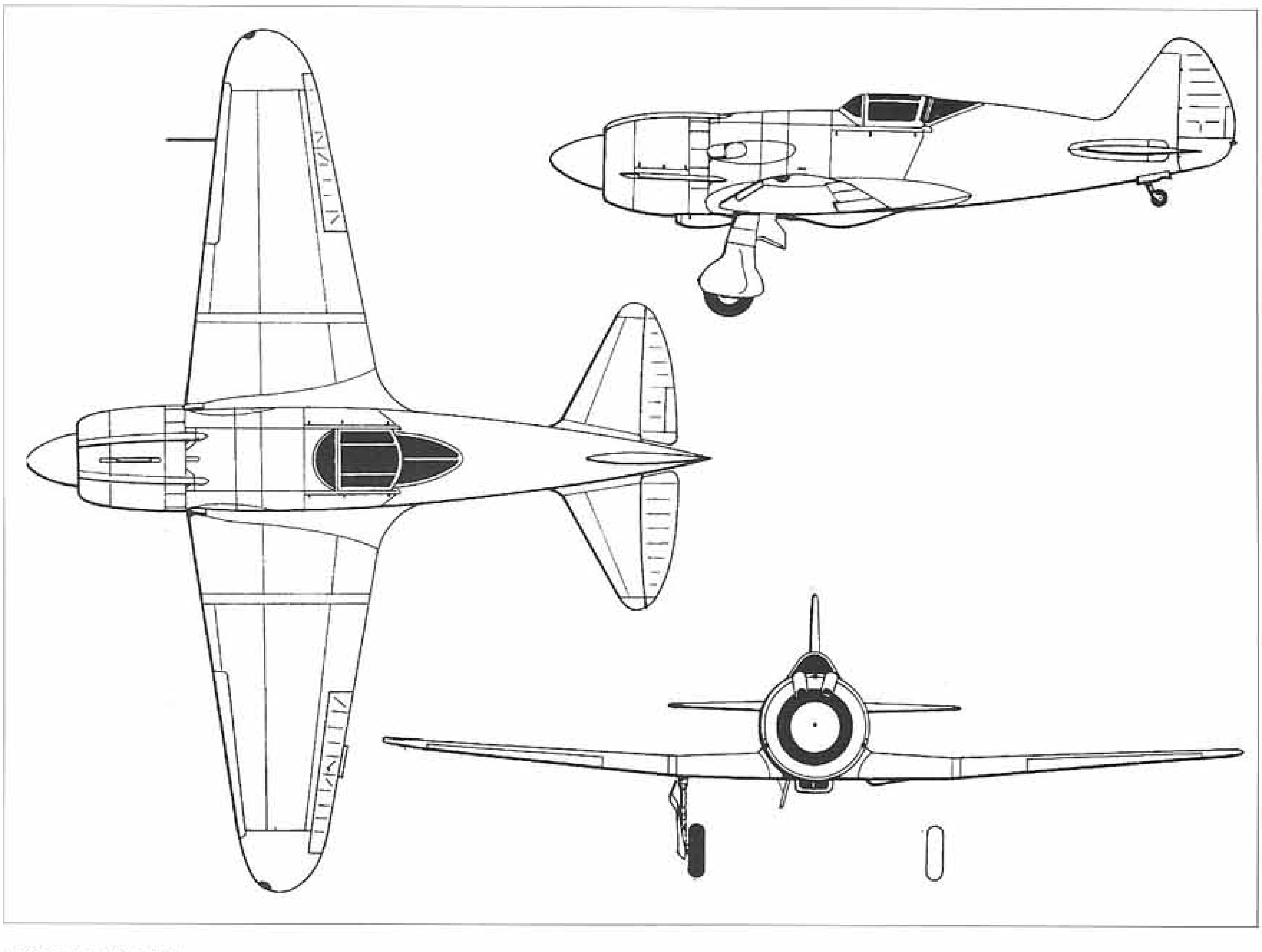
Maximum speed 547km/h (340mph) at sea level, 592km/h (368mph) at 3,400m (11,155ft); climb to 5,000m (16,404ft) 7.95min; service ceiling 9,500m (31,168ft); range, not measured; takeoff run 380m (1,247ft); landing run 400m (1,312ft).

MiG-3/M-82, I-210, IKh, MiG-9

These designations all identified a single type of aircraft derived from the MiG-3 in December 1941. Like the



MiG-3/M-82. (RART/GP)



MiG-3/M-82, I-210.

OKBs of Lavochkin, Gudkov and Yakovlev, the MiG team decided to see if they could fit their fighter with an M-82 (later redesignated ASh-82) engine. In their case the situation was critical; without a replacement for the AM-35A production would come to an end. The difficulty was that the M-82, developed by A D Shvetsov, was a fourteen-cylinder air-cooled radial. It gave excellent power, the takeoff rating of the M-82A version being no less than 1,700hp, falling to 1,330hp at 6,500m (21,325ft). The weight was similar to that of the AM-35A at 850kg (1,874lb); the problem was that the diameter was 1,260mm (49.6in), whereas the MiG fuselage was only 880mm (34.6in) wide.

Nevertheless, M-82A engines were sent from the Perm engine factory to the evacuated GAZ No. 1 at Kuibyshev, where a team under Chief Engineer I G Lazarev devised a 'crash' installation. The factory was still being built, and lacked a roof. No wind-tunnel was available, and all that could be done was to add a light secondary structure to the centre fuselage to fair it neatly behind the circular engine cowling. The underlying welded structure and wing centre section were unaffected.

The cowling comprised a fixed front ring with two oval air inlets at the top, and four hinged panels giving all-round access, the two upper panels incorporating the two supercharger air ducts from the oval inlets. Cooling airflow was controlled by exit gills, hinged not to the cowling panels but to a fixed ring. Immediately downstream, on each side of the centre fuselage, was a large exhaust pipe fed by seven cylinders. Underneath were two drum-type oil coolers similar to those of the MiG-3 but in a common duct. The propeller was initially a VISh-105V.

Data show that fuel capacity was reduced. The only other recorded changes were to make the canopy wider to match the broader fuselage, slightly enlarge both the fin and rudder and fit the latter with a balance horn, and install completely new armament comprising three UBS. One of these 12.7mm weapons was on the upper centreline and the others were on each side just above the level of the wing upper surface, each with a large magazine accommodating 220 rounds. Their blast tubes terminated in the front cowling ring.

In December 1941 five MiG-3 airframes were completed as type IKh, the NKAP designation being I-210. The first was flown by OKB pilot V Ye Golofastov on 2 January 1942. It proved a disappointment. Performance and manoeuvrability were markedly inferior to that of the MiG-3. The main problem was airflow through and around the engine, especially the turbulent flow from the gap under the gills which caused high drag and severe buffet on the tail. One aircraft was flown to Moscow and tested in the CAHI (Central Aerodynamic and Hydrodynamic Institute) T-101 wind-tunnel. It was returned with recommendations which later resulted in the greatly improved fighter known as Ye, or I-211.

Several, possibly all five, I-210 aircraft were sent for operational service on the Kalinin front. Their armament, already much heavier than that of the MiG-3, was augmented by adding two ShKAS. In one of the few photographs of these aircraft in service the blast tube of one ShKAS can be seen just outboard of the starboard air inlet duct. This photograph also shows that, unlike the first prototype, the propeller shaft was fitted with Hucks starter dogs (a kind of bayonet fitting) projecting ahead of the spinner. The Hucks was a vehicle which could be driven up to an aircraft to start its engine by a powered shaft which engaged with this coupling on the front of the propeller shaft.

MiG-9 (I-210, MiG-3/M-82) in front-line service. (Yefim Gordon archive, OKB)

Span 10.2m (33ft 5⅜in); length 8.078m (26ft 6in); wing area 17.44sq m (187.7sq ft) [as MiG-3 except for length].

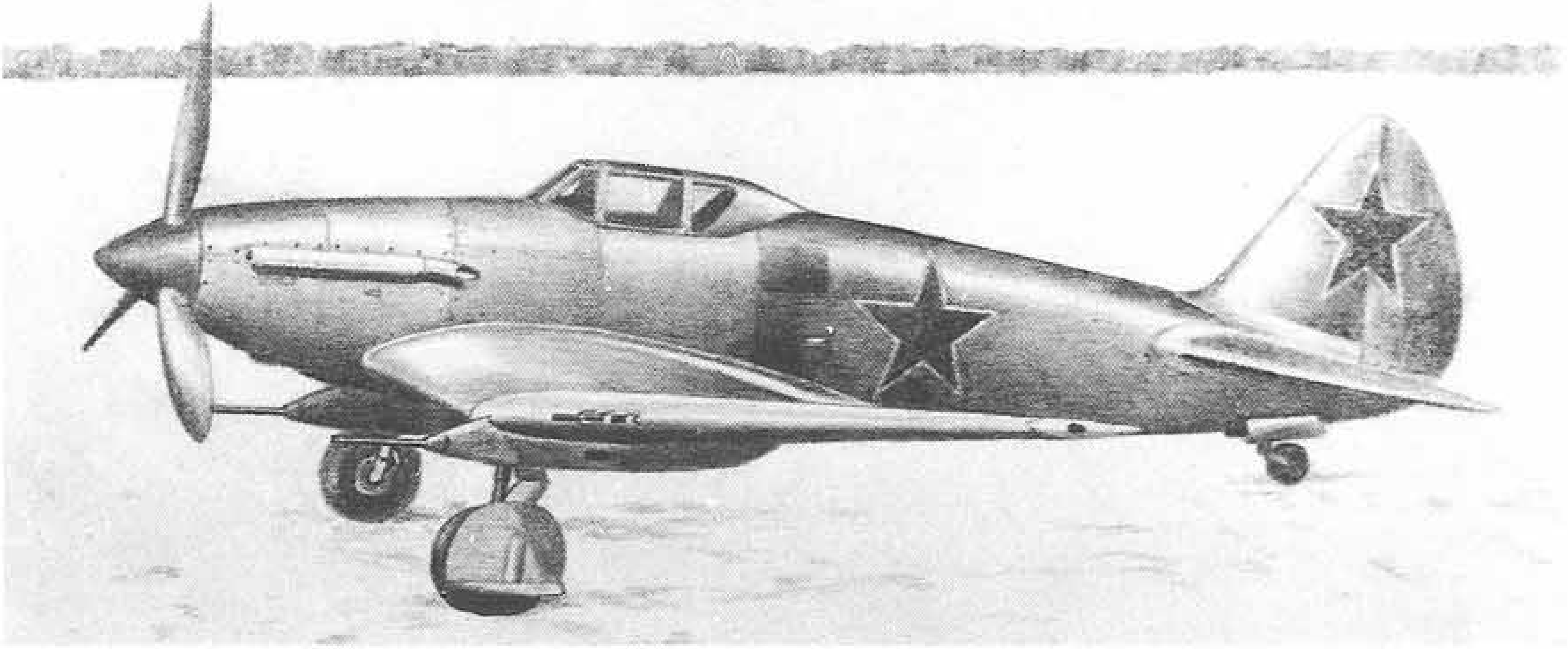
Weight empty 2,720kg (5,996lb); fuel and oil 360kg (794lb); weight loaded (without ShKAS) 3,382kg (7,456lb).

Maximum speed 475km/h (295mph) at sea level, 565km/h (351mph) at 6,150m (20,177ft); climb to 5,000m (16,404ft) 6.7min; range (estimated) 1,070km (665 miles); takeoff run 410m (1,345ft); landing speed 146km/h (90.7mph); landing run 535m (1,755ft).

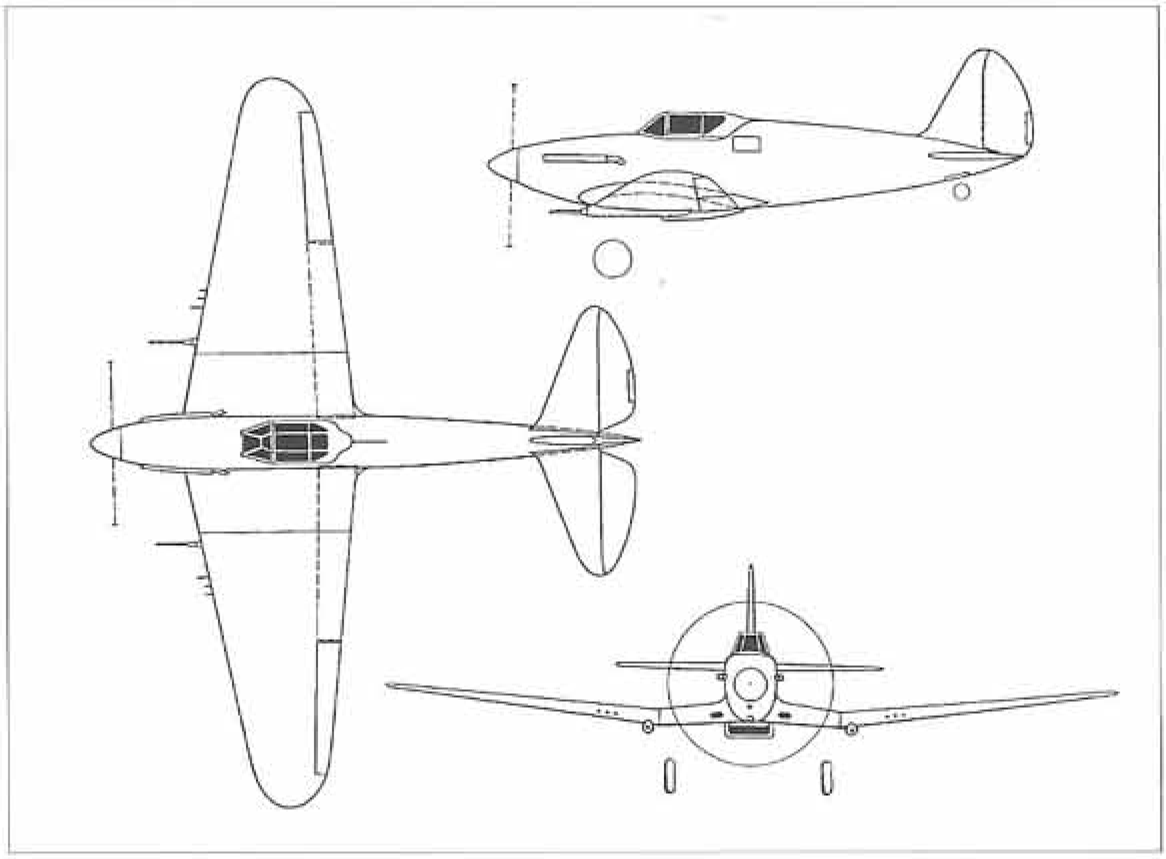
PBSh-1, MiG-4, 65 project

In November 1939 Gurevich, who had been chief designer of the Kochyerigin TSh-3, agreed with Mikoyan that the new OKB should back up the I-200 fighter by an aircraft in the TSh (*tyazholyi shturmovik*, heavy armoured assault) category, principally to destroy enemy armour. Some documents call the project TSh, and others the 65, or I-65, or MiG-4, an even number indicating that the type was not regarded as a fighter. Most describe it as the PBSh-1, *pushechnyi bronirovannyi shturmovik* (cannon-armed armoured assault). This was quickly agreed, and design was started in January 1940.

The PBSh-1 resembled an enlarged I-200. Shavrov gives the intended engine as an AM-37, while another source states that it was a 1,600hp AM-38, though at that time Mikulin had no AM-38 available. Features included a slightly cranked (inverted-gull) wing, welded steel-tube centre section and centre fuselage, wooden outer panels and rear fuselage, and armour protection of the engine and cockpit. Armament would have comprised two very powerful VYa-23 cannon faired in blisters under the roots of the outer wings, each with 96 rounds, plus six 7.62mm ShKAS further outboard each with 750 rounds. Wing racks were to be provided for twelve RS-82 rockets. Under the cockpit there was to be an internal bay able to carry twenty-four FAB-10 bombs, or 280 FAB-2.5 antipersonnel bombs or 120 ZAB-1 incendiary bomblets. It has been reported that the aircraft could also serve as a dive-bomber with an FAB-250 under each wing.



Artist's impression of the PBSh-1. (Yefim Gordon archive)



PBSh-1.

Design, led by Matyuk, initially concentrated on the armour, which with thickness varying from 7.5 to 15.5mm was calculated to weigh no less than 1,390kg (3,064lb). A detailed mock-up was reviewed on 24 July 1940, but by this time the OKB had had second thoughts and switched to the PBSh-2. Data below are estimates.

Span 13.5m (44ft 3½in); length 10.145m (33ft 3⅜in); wing area 30.5sq m (328.3sq ft).

Weight empty 4,850kg (10,692lb); maximum weight loaded 6,024kg (13,280lb).

Maximum speed at sea level 449km/h (279mph); service ceiling 7,600m (24,935ft); range 900km (559 miles).

PBSh-2, MiG-6 project

At first glance this extraordinary project looks like a 'bi-mono' aircraft, fitted with an upper wing to assist heavily loaded takeoff and which could then be jettisoned for maximum speed. In fact the PBSh-2 was a true biplane, adopted to make the aircraft better suited to front-line antitank missions. Compared with a monoplane, it was expected to have shorter takeoff and landing, to have better manoeuvrability and stability and generally to be easier to fly. It replaced the PBSh-1 as an OKB project in July 1940.

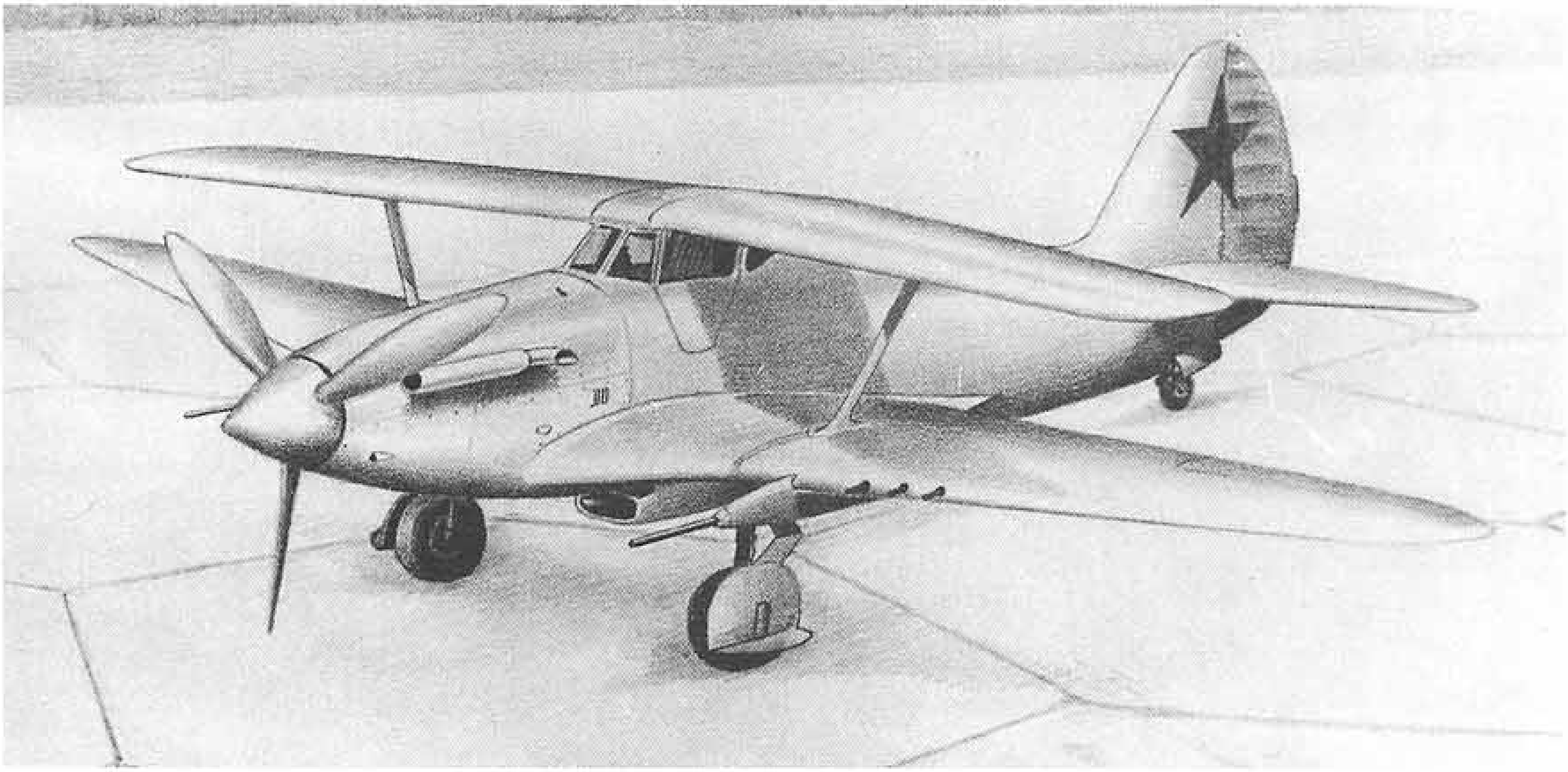
In general it was a smaller version of the PBSh-1, with an almost identical powerplant group, centre section, landing gear, cockpit and armour, apart from adding a jettisonable side door. The outer wings were smaller, and tapered on the trailing edge only. Above the cockpit was added a small forwards-swept upper wing, without movable surfaces, braced by single struts to the tips of the lower centre wing. Armament was as before, except that the cells in the fuselage for bomblets changed places with the fuel tanks in the centre wing.

It is not recorded how this proposal was received by the NII-VVS or NKAP. Work continued until late 1940, when it was clear that the Ilyushin BSh-2 would be the aircraft adopted, as the Il-2.

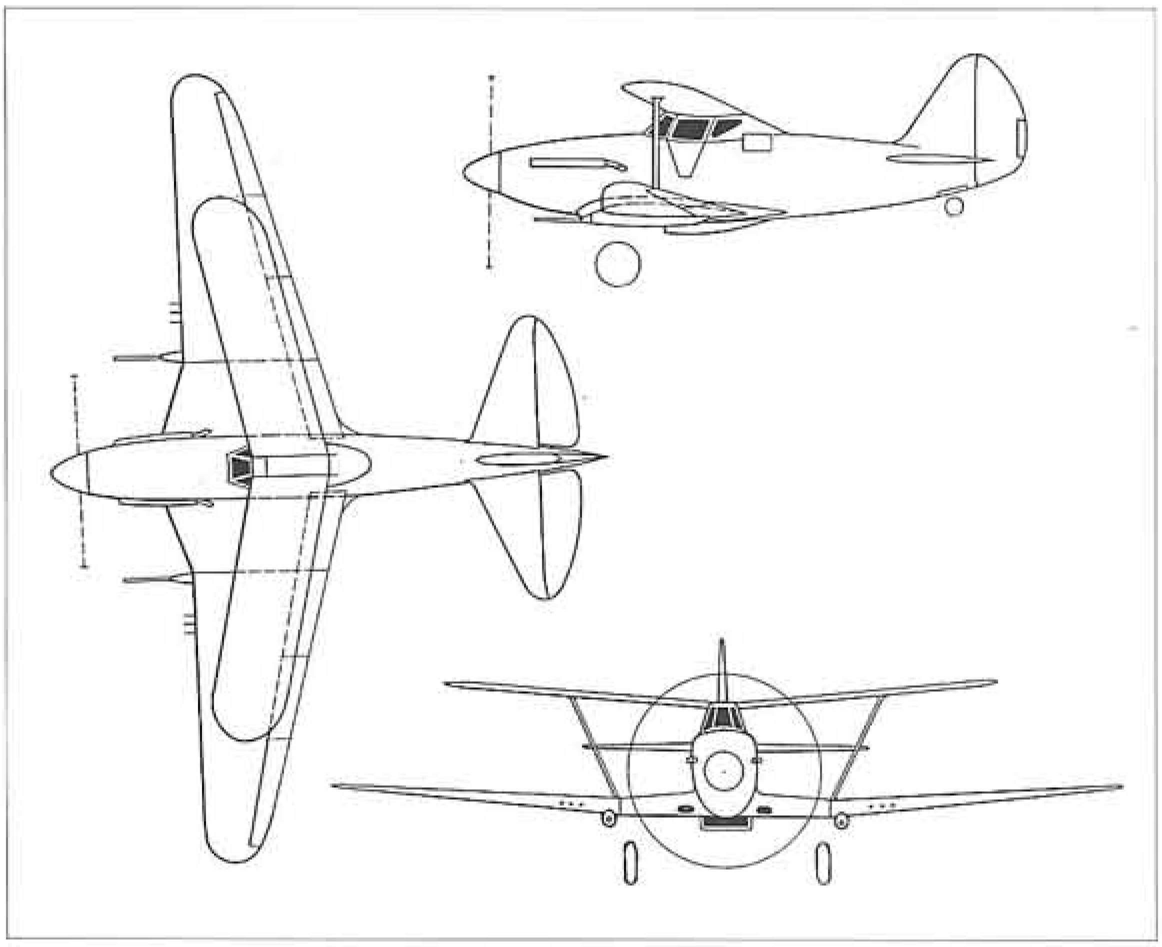
Span (lower) 12.4m (40ft 8.19in), (upper) 8.6m (28ft 2½in); length 8.85m (29ft ½in); wing areas (lower) 22.14sq m (238sq ft), (upper) 10.26sq m (110.4sq ft).

Weight empty not recorded; maximum weight loaded 4,828kg (10,644lb).

Maximum speed at sea level 426km/h (265mph); range 740km (460 miles).



Artist's impression of the PBSh-2 project. (Yefim Gordon archive)



PBSh-2.

DIS, DIS-200, T, MiG-5

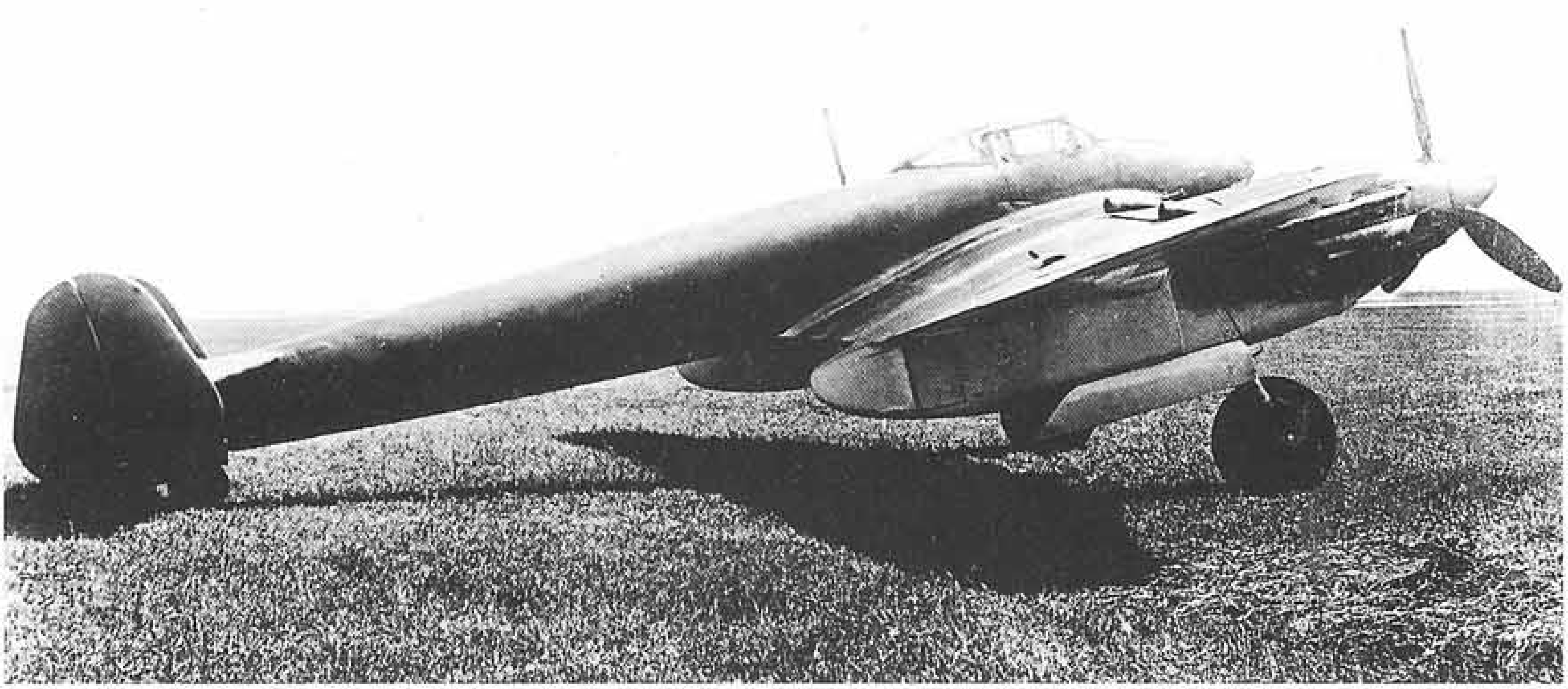
All these designations referred to a single prototype; indeed some documents also call it the DIS/2AM-37, because it was common Soviet practice to include the engine(s) in the designation. Apart from being a single-seater, of very mixed construction, it had little in common with its single-engined predecessors.

It was intended as a multirole-aircraft, its primary function being to escort long-range bombers, such as the TB-7 (Pe-8) and Yer-2, but with the ability also to be equipped for bombing, dive-bombing, torpedo dropping and reconnaissance. The principal designation stemmed from *dvukhmotornyi istrebitel' soprovozhdeniya*, twin-engined fighter escort. The OKB considered that it had a good chance of succeeding in this field, despite such competitors as the Polikarpov TIS, Tairov OKO-6bis (Ta-3) and Grushin Gr-1.

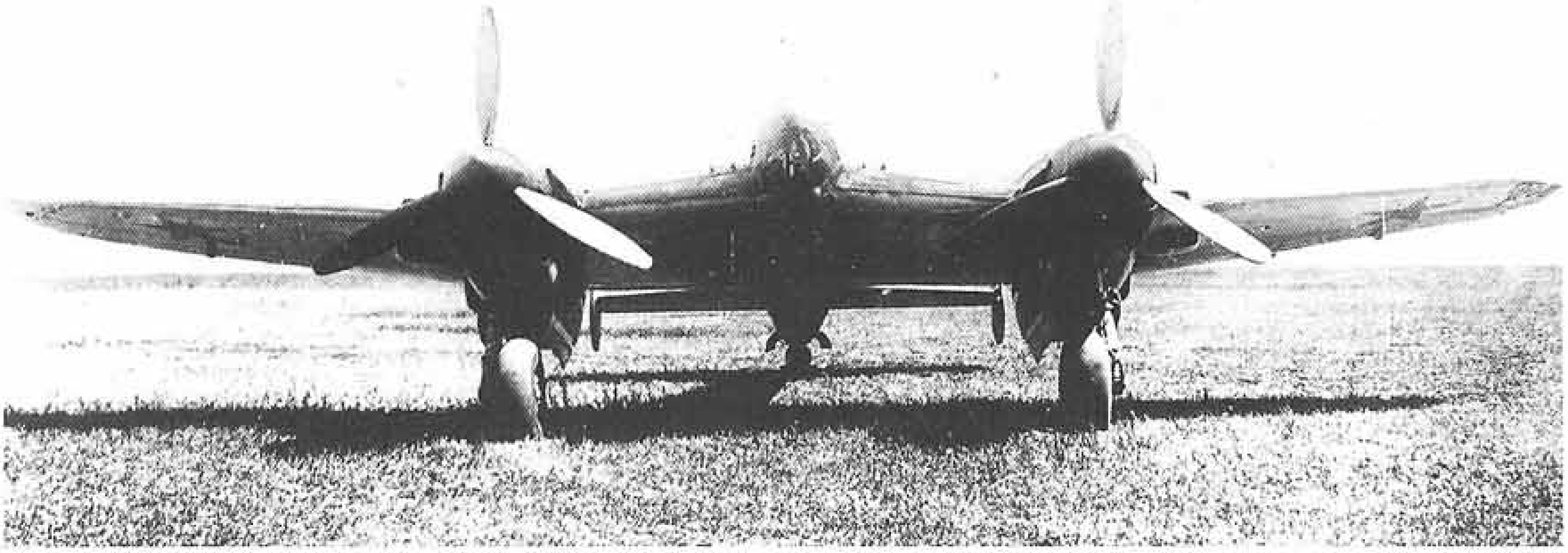
Work began, with a contract for a single prototype, in August 1940, the OKB designation being Aircraft T. In order to obtain the longest possible range it was hoped to use two of the economical diesel engines of A D Charomskiy. These were still under development, and so the OKB settled instead for Mikulin's AM-37, with which it was familiar.

Structurally this aircraft followed its predecessors, except that as there was no engine on the nose the fuselage could be very slim. The nose was duralumin, and could be removed from the forward fuselage for access. The forward fuselage was also duralumin, based on three strong D16 longerons. It was attached by bolts to the front spar and root ribs of the wing. The centre fuselage, attached behind the cockpit, was made of *delta*, using eight wrapped layers of *shpon* veneer and bakelite-ply skin on an underlying structure with phenol-impregnated wooden longerons and pine frames. The rear fuselage was based on welded steel tubes with duralumin skin.

Aerodynamically the centre wing had a horizontal underside and thus



DIS. (OKB)



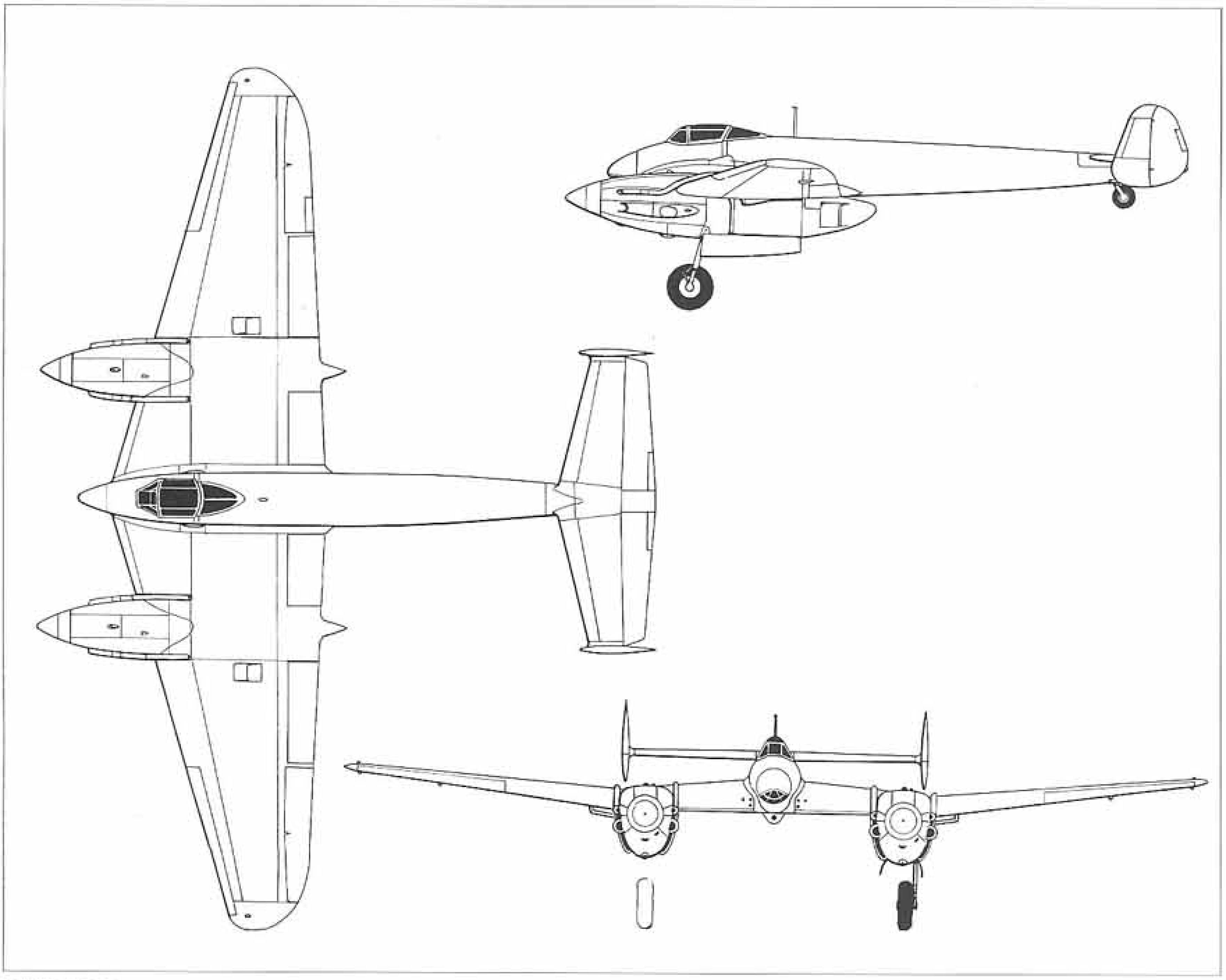
DIS. (OKB)

slight anhedral on the upper surface, whereas the outer wings had 7.5° dihedral. The wing's sharp taper was almost entirely on the leading edge. Pneumatically driven split flaps were fitted inboard and outboard of each nacelle under the centre wing. Slotted flaps were fitted to the outer wings, occupying the trailing edge to the ailerons. Each section of flap was D16 with veneer skin.

The centre wing followed the usual metal construction, with D16 spar webs, 30KhGSA booms (T-section on the main spar and ¬-section on the rear spar) and pressed-sheet ribs. The outer wings were again wood, with a main and false rear spar and built-up pine ribs.

The tailplane had two wooden spars. The front spar was pivoted to the fuselage and the incidence was controlled by an irreversible electric screwjack acting on the rear spar. The twin fins were wood, with veneer skin, but all control surfaces were of D16 and skinned in fabric. The flight controls again used cables for the rudders and rods/levers for the elevators and ailerons. The port elevator had an electrically driven trimmer (OKB drawings show trimmers on both elevators), and both rudders and the starboard aileron had manual screw-driven trimmers.

Each engine installation had features in common with the MiG-3, including the VISh-61Sh propeller, the welded-tube mounting, and twin drum-type oil coolers in tunnels on each side. In contrast, the glycol coolant was ducted through a radiator matrix on each side of the nacelle, only 160mm (6.3in) wide but extending the full height of the nacelle under the wing. Airflow entered through a narrow vertical slit and left through a hinged flap under the trailing edge, controlled either by a thermostat or directly by the pilot. The supercharger air inlets were in the leading edge immediately outboard of the cowling, and the exhaust was piped over the wing. OKB drawings also show a small ram intake under each



DIS/2AM-37.

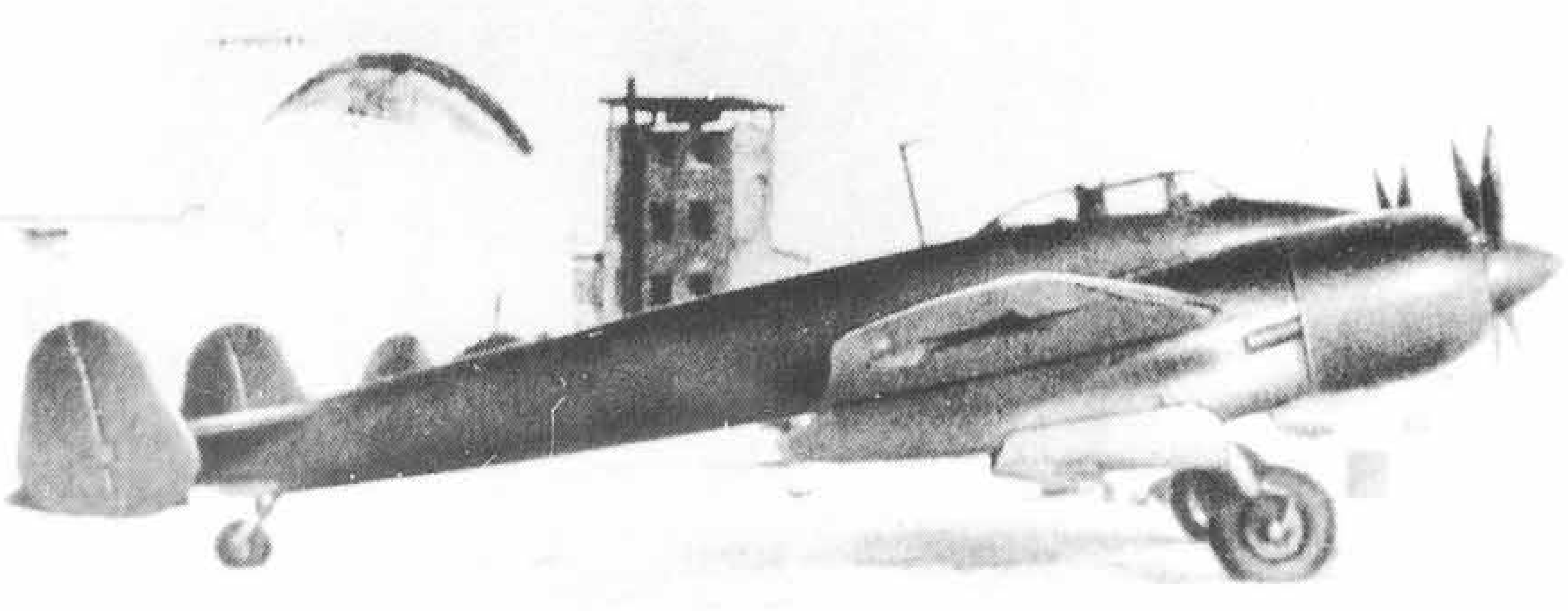
outer wing with a duct to a flush flap-controlled exit further aft on the upper surface. This appears to have been an aftercooler for an ethylene-glycol circuit cooling the air downstream of the supercharger.

Each main landing gear had a single leg of high-strength steel with a levered-suspension shock strut at the bottom carrying an axle on its inner side. When extended, the legs sloped forwards for maximum stability on the ground; ground angle was 16°. They were mounted outboard in the nacelle so that the wheels were under the nacelle centreline, the track being 4.6m (15ft 1.1in). Tyre size was 950 × 300mm. Each unit retracted backwards pneumatically. As in the single-engined fighters, the system drew air from bottles charged by engine-driven compressors at 150ata (2,200lb/sq in). Fed through restrictor valves, the same system served the drum-type wheel brakes. The tailwheel was also fully retractable into a bay with twin D16 doors.

A total of 2,709 litres (596gal) of fuel was housed in four self-sealing tanks in the centre wing and two in the fuselage. One fuselage tank had a capacity of 765 litres (168gal). The pilot sat on the centreline in the nose, under a jettisonable sliding canopy. He boarded via a retractable ladder behind the wing on the left. His view was generally outstanding, and as Aircraft T was intended to be representative of both the MiG-5 fighter and the MiG-2 bomber/reconnaissance aircraft the underside of the nose was glazed with four Plexiglas panels. His adjustable seat was very well protected by armour up to 9mm thick, and immediately behind it was the RSI-4 radio, an RPK-2 direction-finding loop and AFA-1 camera. Other equipment included KPA-3bis oxygen and a retractable landing light.

The first prototype flew without armament. According to OKB records the gun armament was to comprise two underslung gondolas each housing an MP-6 cannon of 23mm calibre. In contrast the drawings show a single VYa-23 installed in a gondola under the centreline, fed by a 96-round magazine between the cockpit and the forward fuselage tank, plus a UBS-12.7 in the bottom of each wing root, with the magazine along the underside of the wing just ahead of the spar, and a pair of ShKAS-7.62 mounted in the top of each wing root, with magazines in front of the spar.

The bomber, Aircraft T, was projected in three versions, in each case without the 23mm gun(s). In the first, external racks would be provided for a tandem pair of FAB-500 (1,102lb) bombs, or three FAB-250. In the second, a single FAB-1000 would be carried, and in the third, a 45-AN parachute-equipped torpedo.



DIS/2M-82. (Yefim Gordon archive)

In January 1941 the DIS fighter version was redesignated MiG-5. The single prototype was painted, probably dark grey or green with a light colour underneath, and rolled out from GAZ No. 1 on 15 May 1941. On the same day it began taxi trials in the hands of its pilot, Aleksandr I Zhukov. He made the first flight on 19 May. On the whole he and his colleague V N Savkin thought the DIS an excellent aircraft, though its landing speed of 148km/h (92mph) was judged too high, and made testing from Khodynka hazardous.

Two of the modifications required were to add duralumin automatic slats ahead of the ailerons, and to arrange for the ailerons to droop 20° when the flaps were lowered. The propellers were changed for four-blade AV-9BL-149 units, which immediately increased the maximum speed from the very disappointing figure of 560km/h to that given below. If further modifications could have been made – to improve the leading edge with the slats housed and avoid turbulence behind the ShKAS guns – 640km/h would have been expected. A remaining shortcoming was heavy lateral control.

LII trials followed from July until October 1941. This was marginally considered the best of the escort fighters, and GAZ No. 1 was expecting to receive a production order when it was ordered to evacuate. While the designers went to Kuibyshev, the DIS flew to Kazan, where it languished while a factory was sought that could build it. Meanwhile, it was increasingly judged that such aircraft were not needed.

Span 15.1m (49ft 6½in); length 10.875m (35ft 8¼in); wing area 38.9sq m (418.7sq ft).

Weight empty 5,446–6,140kg (12,000–13,536lb); fuel 1,920kg (4,233lb); weight loaded, T, fighter configuration 7,605–8,060kg (16,766–17,769lb),

Maximum speed (estimated) 610km/h (379mph) at 6,800m (22,310ft); climb to 5,000m (16,404ft) 5.5min; service ceiling (approximately 10,900m (35,761ft); range (estimated) 2,280km (1,417 miles).

DIS-200, IT, MiG-5, DIS/2M-82

To try to overcome the shortage of suitable engines, this second prototype twin-engined escort fighter was designed to be powered by 1,700hp M-82F engines, obtained from Perm at the same time as engines for the IKh, I-210. In most other respects it was similar to its predecessor. The supercharger inlets remained in the leading edge but were narrower and deeper. The oil coolers were in a duct under the engines, and the 'mystery' air ducts in the outer wings were omitted. Hucks starter dogs were provided on the front of each propeller shaft, but, unlike the I-210, each propeller had four blades.

The surviving OKB drawing again shows the IT with a single VYa-23 gun, though photographs show that, as described in written records, two MP-6 guns were fitted in gondolas under the wing roots. The nose was again glazed, but with eight panels covering a slightly larger area. The drawing shows outer-wing slats, which is to be expected, but omits trim tabs from the rudders and starboard aileron. The meaning of DIS-200 is not known. Shavrov states that this second aircraft was never completed, 'because the Pe-2 was already performing these roles', while another MiG book states that it was completed but never flown.

In fact, the incomplete aircraft was taken to Kuibyshev and finished there. Painted dark above and light underneath, like its predecessor, it was first flown on 22 January 1942, the pilot being G M Shiyanov of the NII-VVS. Its subsequent testing took place at Kazan, but it eventually languished alongside its predecessor. Productive capacity was sought, but by 1942 it was considered that, as the only escort missions required were short range, any that were needed could be flown by existing frontal fighters.

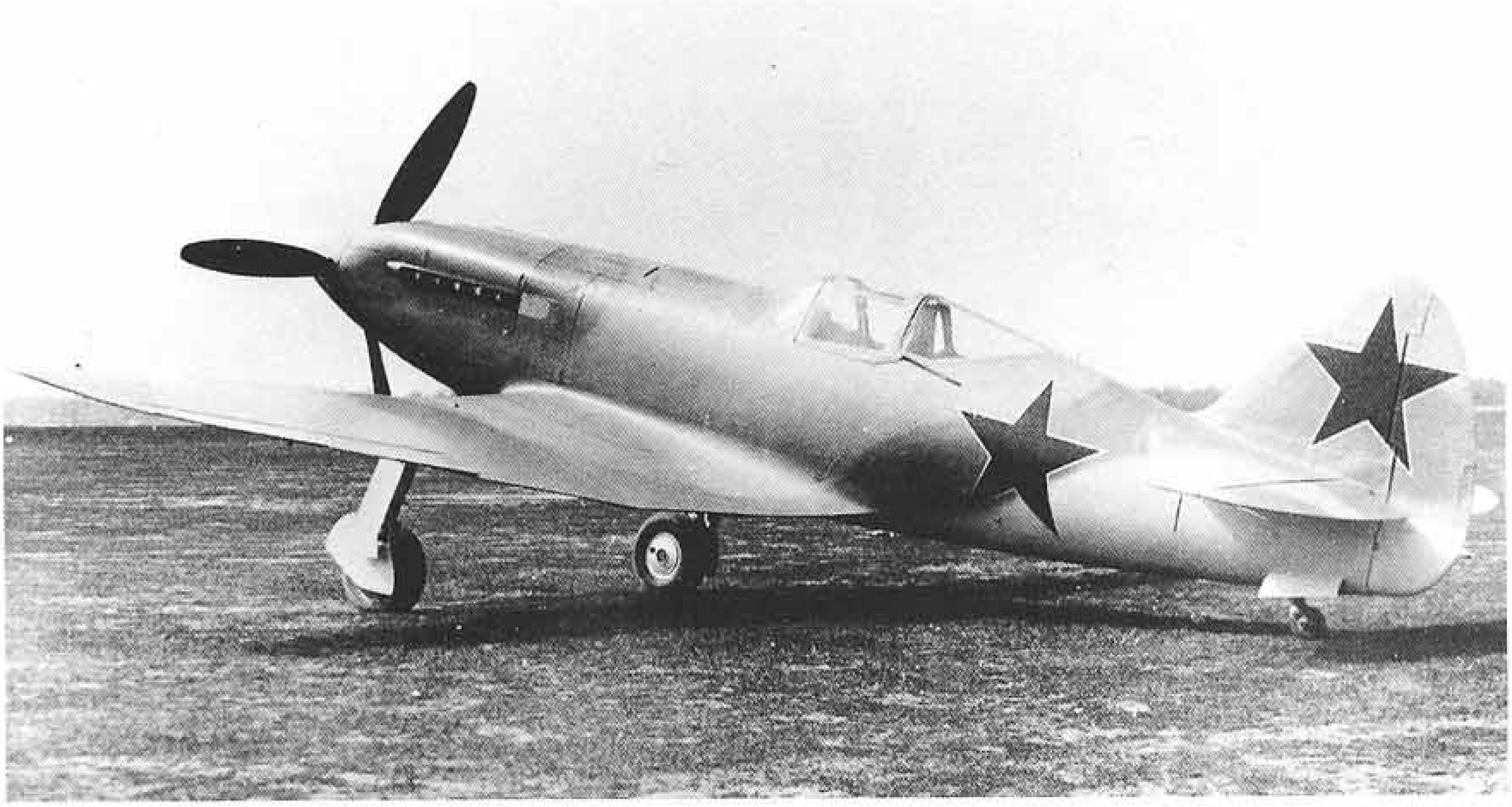
Dimensions as DIS, T, except length 12.14m (39ft 10in).

Weight empty 5,865kg (12,930lb); fuel as before 1,920kg (4,233lb), weight loaded 8,000kg (17,637lb).

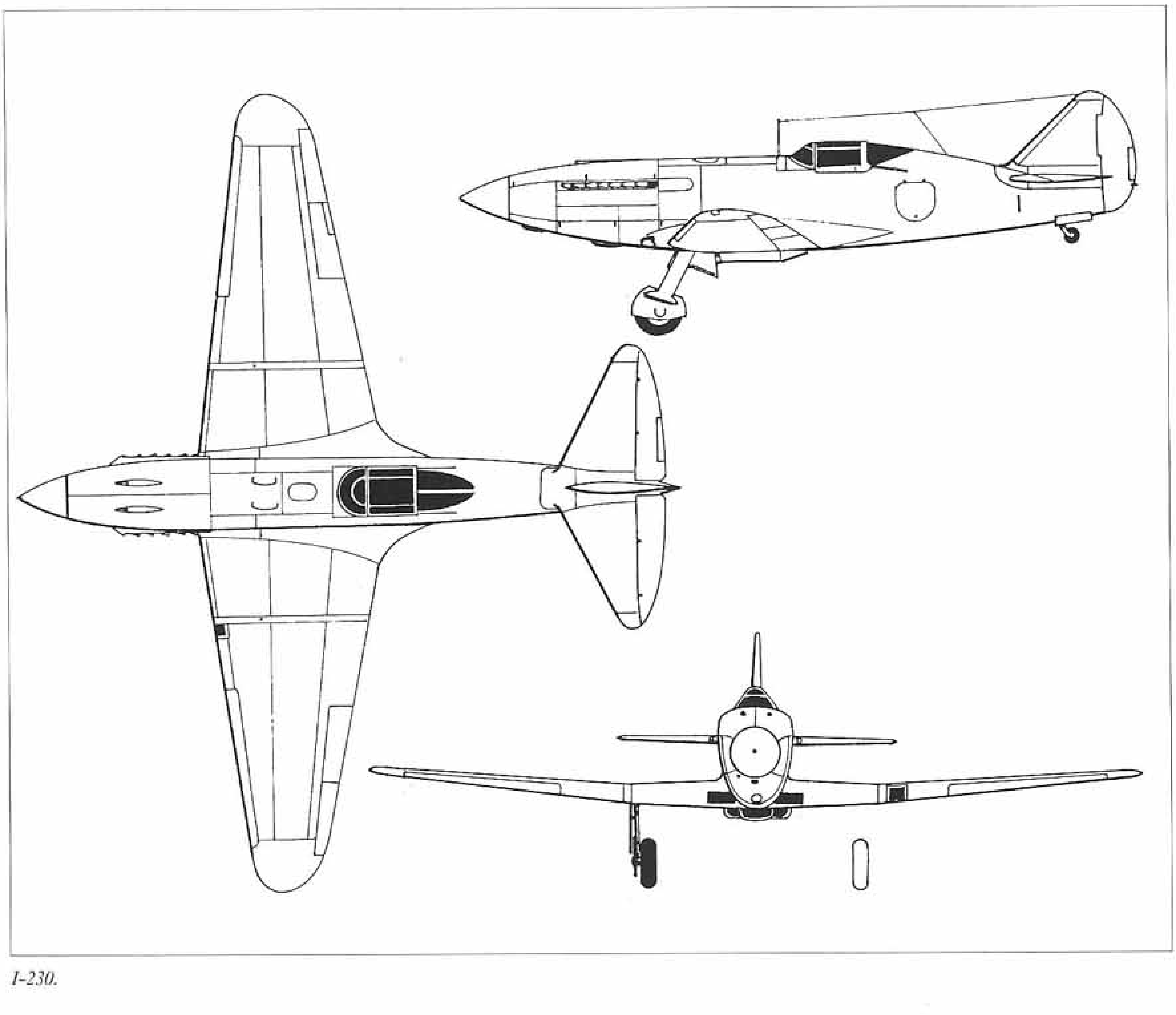
Maximum speed (estimated) 604km/h (377mph) at 5,000m (16,404ft) climb to 5,000m (16,404ft) 6.3min; service ceiling 9,800m (32,152ft); range 2,500km (1,553 miles).

I-230, D, MiG-3U

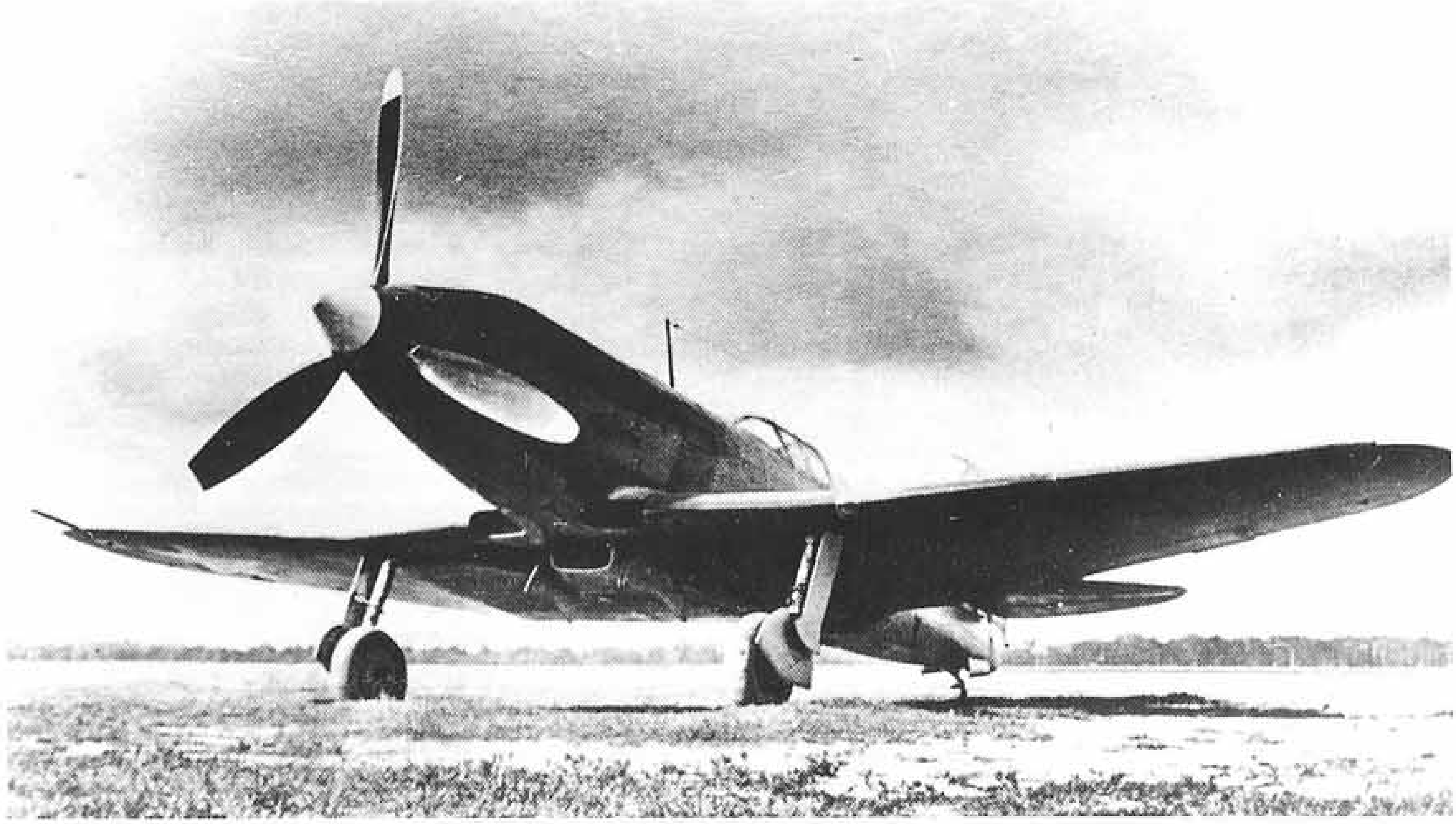
Aircraft D was the OKB's chief contender for the next generation to succeed the MiG-3. It has sometimes been suggested that its designation stemmed from *dalnostniy* (long range), but it had less fuel than its predecessors. It has also been described as a



I-230 No. 01. (OKB)



I-230.



I-230 No. 01 later. (Yefim Gordon archive)

high-altitude fighter, but in fact it was designed to be the best fighter at all altitudes. What can be confirmed is that its NKAP designation was I-230 (*istrebitel*, fighter), and if it had entered service it would have been the MiG-3U (*uluchshenniy*, improved).

Though the starting point was the MiG-3, in order to use existing factory tooling as far as possible, the I-230 eventually emerged as an almost totally different aircraft. As far as possible, it incorporated recommendations from pilots who had flown the MiG-3 in combat. Sadly, the one feature that the OKB most wished to change, the engine, remained the same. The prototype shop built six of these aircraft, all fitted with reconditioned AM-35A engines.

Aerodynamically the new fighter was possibly the best in the world at that time. The new fuselage was almost perfectly profiled, and lengthened amidships (enabling all fuel to be put in one tank). The cockpit was made slightly wider and, even though it was moved 370mm (14.57in) even further aft, pilot view in flight was improved, especially to the rear where the large fixed transparent panels curved down more sharply. Relative to the rear fuselage (itself moved aft) the tailplane was mounted 350mm (13.8in) further back and 200mm (7.9in) higher, level with the top of the fuselage. The fin was increased in area, and the nose of the rudder extended between the two upper hinges to form an aerodynamic balance.

The beautiful engine installation was totally redesigned, though still based on a truss welded from 30KhGSA tube. The oil and glycol radiators were rearranged in a close group under the centre wing, the glycol matrix being recessed deep in the fuselage to give a shallower external duct to reduce drag. The supercharger inlets in the wing roots were of the 'letterbox' type, as on the DIS, and the engine was fitted with individual ejector exhaust stubs for each cylinder.

Structurally the main change was elimination of the welded-tube centre fuselage. Aft of the steel firewall the fuselage and fin comprised a single semimonocoque made from three layers of 1mm *shpon* veneer. Each outer wing retained plywood skin, but was based on a main spar similar to that in the centre section, with D16 webs and booms machined from 30KhGSA steel. Improved balanced ailerons were fitted, as well as leading-edge slats, the pitot tube being mounted under the starboard wing below the slat. The main-leg shock strut was improved in design, and its door was made as a single rectangle, separate from the wheel half-door which moved up and down with the wheel. An upwards-hinged door was provided in the left side of the fuselage behind the cockpit, for easy access to the radio, oxygen, compressed-air cylinder and other systems. This was a feature of subsequent piston-engined MiG prototypes.

There were major systems changes, the most important being that the four protected metal fuel tanks were replaced by a single self-sealing fuselage tank of rubberized fabric, of 440lit (96.8gal) capacity ahead of the cockpit. Another major change was that, influenced by reports from units fighting with the MiG-3, the armament comprised two ShVAK 20mm mounted above the engine, each fed with 150 rounds. No provision was made for underwing weapons.

I-230 No. 01 was constructed entirely at Kuibyshev, and first flown (it is believed, by Golofastov) on 11 August 1942. No radio was then installed. Reports on its handling characteristics vary.

In addition to the prototype, five preproduction aircraft were completed in the OKB workshop. Aircraft No. 02, the first with radio, had extended wingtips, with the pitot tube near the tip beyond the extended-span slat, and a high-solidity (broader chord) AV-5A propeller for better performance at high altitudes.

The five preproduction aircraft were sent to No. 12 GvIAP (Guards fighter aviation regiment) – not No. 1, as often reported – on the Kalinin front. No more could be built, because there were no available engines.

Span 10.2m (33ft 5½in), (No. 02) 11m (36ft 1in); length 8.62m (28ft 3⅜in); wing area 17.44sq m (187.7sq ft), (No. 02) 18sq m (193.8sq ft).

Weight empty 2,612kg (5,758lb); fuel 324kg (714lb); oil 56kg (123.5lb); weight loaded 3,285kg (7,242lb).

Maximum speed, 560km/h (348mph) at sea level, 660km/h (410mph) at 6,000m (19,685ft); climb to 5,000m (16,404ft) 6.2min; service ceiling 11,500m (37,730ft), (No. 02) 12,000m (39,370ft); range 1,300km (808 miles).

I-231, 2D

During 1942 the engine KB of A A Mikulin qualified their most powerful engine yet, the AM-39, and managed to put it into limited production. Installationally similar to the previous AM-35, -37 and -38, it was cleared to run at higher rpm and with increased boost pressure. The basic AM-39 was rated at 1,800hp for takeoff, and at 1,300hp at 7,100m (23,294ft). This engine was eagerly accepted by the MiG OKB for an improved version of the Aircraft D. Designated 2D, it received NKAP designation I-231.

Though it cannot be seen in photographs, the main difference in the 2D was that the fuselage was an all-metal semimonocoque. This saved a considerable amount of weight. In most other respects the additional prototype was similar to Type D. The propeller was an AV-5L, as fitted to the preproduction I-230 fighters. A visible change was to revert to the low tailplane, and increase the taper of the top of the fuselage behind the cockpit.

The more powerful engine was matched by a redesigned glycol and oil radiator group, the former having a deeper inlet near the wing leading edge. The panel of heat-resistant steel immediately downstream of the exhaust pipes was made considerably larger. The only other recorded change was to increase magazine capacity to 160 rounds per gun. No explanation has been found for the slight increase in fuel mass or for the extraordinary reduction in lubricating oil, which might have been expected to increase.

The 2D was built and flown in 1943 (a document giving a first-flight date in February of that year is not considered reliable). The main testing was in the hands of NII-VVS pilots P M Stefanovskiy and Yu A Antipov. Most uncharacteristically, Stefanovskiy wrote the aircraft off in a landing accident. Even Shavrov grudgingly admitted that the 2D was 'quite impressive', but production was impossible; there were no engines and no available aircraft factory.

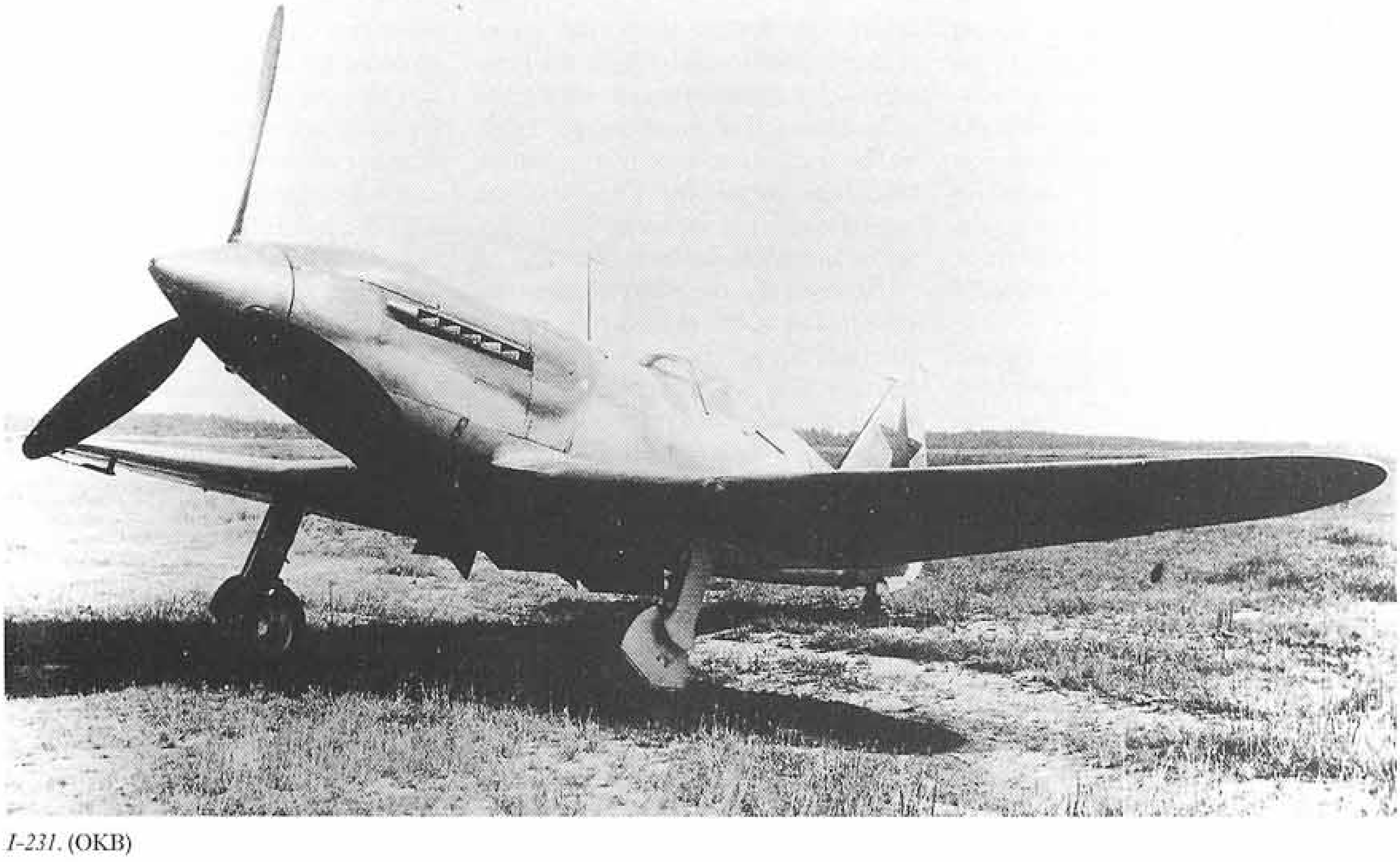
Dimensions, as I-230, D.

Weight empty 2,583kg (5,694lb); fuel 333kg (734lb); oil 34kg (75lb); weight loaded 3,287kg (7,242lb).

Maximum speed 600km/h (373mph) at sea level, 707km/h (439mph) at 7,100m (23,294ft); climb to 5,000m (16,404ft) 4.5min; service ceiling 11,400m (37,400ft); range 1,350km (839 miles).

I-211, Ye

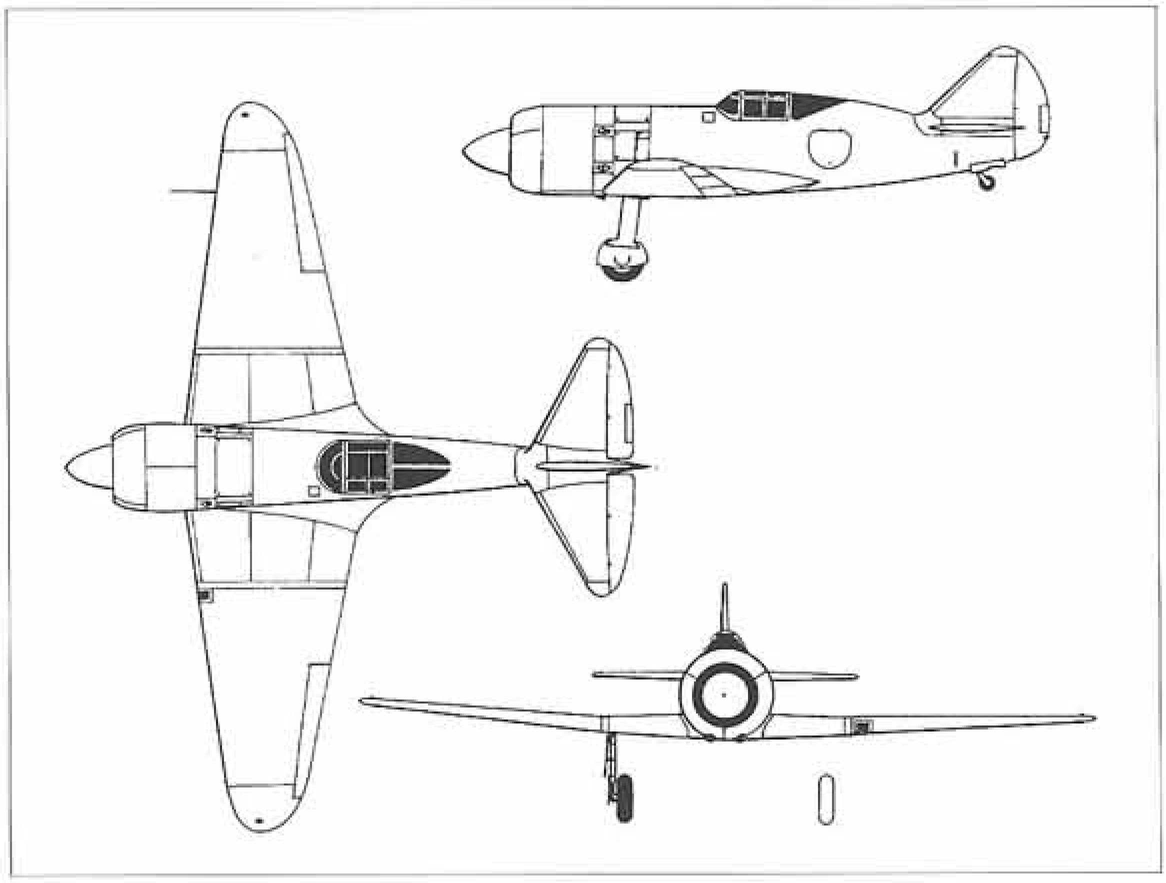
In their desperate search for an engine for a production fighter derived from the MiG-3 the MiG OKB consistently failed to find a liquid-cooled engine from the Mikulin KB (except for prototype engines), but knew that A D Shvetsov's air-cooled radials of the M-82 (by 1942 called ASh-82) family were in full production at



I-231. (OKB)

nearby Perm. Having produced an unimpressive aircraft with this engine in the I-210, the careful testing of this aircraft in the T-101 wind-tunnel at CAHI showed that considerable improvements were possible.

Accordingly, in February 1942 work went ahead on the Ye (written E in Russian), with NKAP designation I-211. This time the OKB had test results from CAHI and the cooperation of the Shvetsov KB. Compared with the I-210 the main difference lay in the completely redesigned fuselage. The engine was the ASh-82F, with a takeoff rating of 1,700hp, driving a VISh-105V propeller, without Hucks starter dogs. According to Shavrov the engine was moved forwards to improve the centre-of-gravity position, but in fact it was moved a very short distance back, and the overall length of the aircraft was shorter.



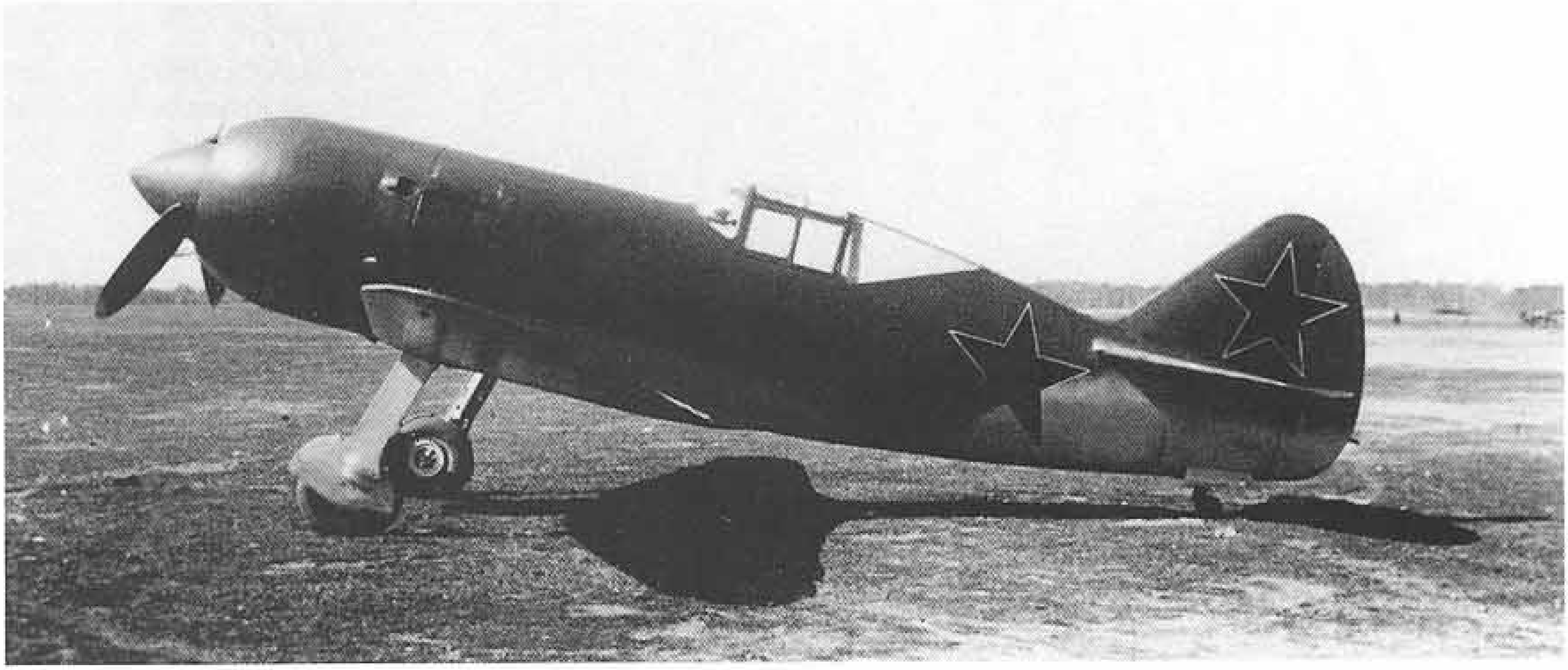
I-211, Ye.

The cowling was redesigned, fitting very tightly with constant diameter. The aerofoil-profile front cowl was made in three quickly removable 120° segments, and the main drum comprised a small fixed lower portion and large left and right doors hinged together on the upper centreline. This new cowling gave all-round access, yet was hermetically sealed when closed. Immediately to the rear were upper and lower exhaust pipes on each side, behind which was a large exit for cooling air controlled by a hinged door. The supercharger inlet was inside the cowling, but the two drum-type oil coolers were in the wing roots.

Downstream the fuselage blended perfectly with the cowling, with no gaps except the rectangular duct for cooling air. Structurally the fuselage resembled the I-230 and I-231, with the cockpit moved 245mm (9.65in) back, an access door added behind it on the left side, the tailplane raised and the integral fin increased in chord. Elimination of the steel-tube truss helped to make the I-211 significantly lighter than the I-210.

The pitot tube and landing light were as on the I-230. Armament comprised two ShVAK, each with 150 rounds, mounted in the centre wing near the aircraft centreline, with the blast tubes in the bottom of the engine cowling. Altogether the I-211 was an outstanding aircraft, yet it had two unexpected features. The wings had no slats, and the cockpit canopy did not slide but hinged to the right, and so could not be opened in flight.

Golofastov made the first flight, which (according to different accounts) took place on 18 December 1942, in February 1943, in August 1943 or in summer 1943. It was widely considered that the I-211 was the best Soviet fighter then flying, and among the fastest. The OKB managed to build a small preseries, possibly ten, which did brilliantly in action on the Kalinin front and resulted in a clamour for more. Unfortunately, no factory was



I-211. (Yefim Gordon archive)

available, and all ASh-82FN engines were wanted for the La-5FN, which was already in mass-production.

Belyakov reported that in 1942 the OKB was ordered by the NKAP to send drawings of the engine installation and of the I-210/211 slats to the Lavochkin OKB. Histories of the Lavochkin bureau state that the LaGG-3/M-82 engine installation, which led to the La-5, was designed with no help except that of the Shvetsov team, and that *Lavochkin's slat design was used on the MiG fighters*!

Dimensions as MiG-3 except length 7.954m (26ft 1in).

Weight empty 2,528kg (5,573lb); fuel 324kg (714lb); oil 56kg (123.5lb); weight loaded 3,100kg (6,834lb).

Maximum speed 549km/h (341mph) at sea level, 670km/h (416mph) at 7,000m (22,966ft); climb to 5,000m (16,404ft) 4min; service ceiling 11,300m (37,073ft); range 1,140km (708 miles).

I-220, A, MiG-11

Though the original Polikarpov Aircraft Kh had been especially intended to fight at high altitudes, this tended to be forgotten after the Great Patriotic War started in June 1941 because nearly all the air combats took place at low level. Nevertheless, there remained a need for high-altitude fighters, if only to shoot down the Junkers Ju 86P and Ju 86R reconnaissance aircraft which flew over the Soviet Union with impunity at heights of up to 13,700m (44,950ft). A requirement for a new VP (*vysotnyi perekhvatchik*, high-altitude interceptor) had been issued in early 1941, but a contract for a prototype was not placed with the MiG OKB until late 1942, after it had returned to Moscow.

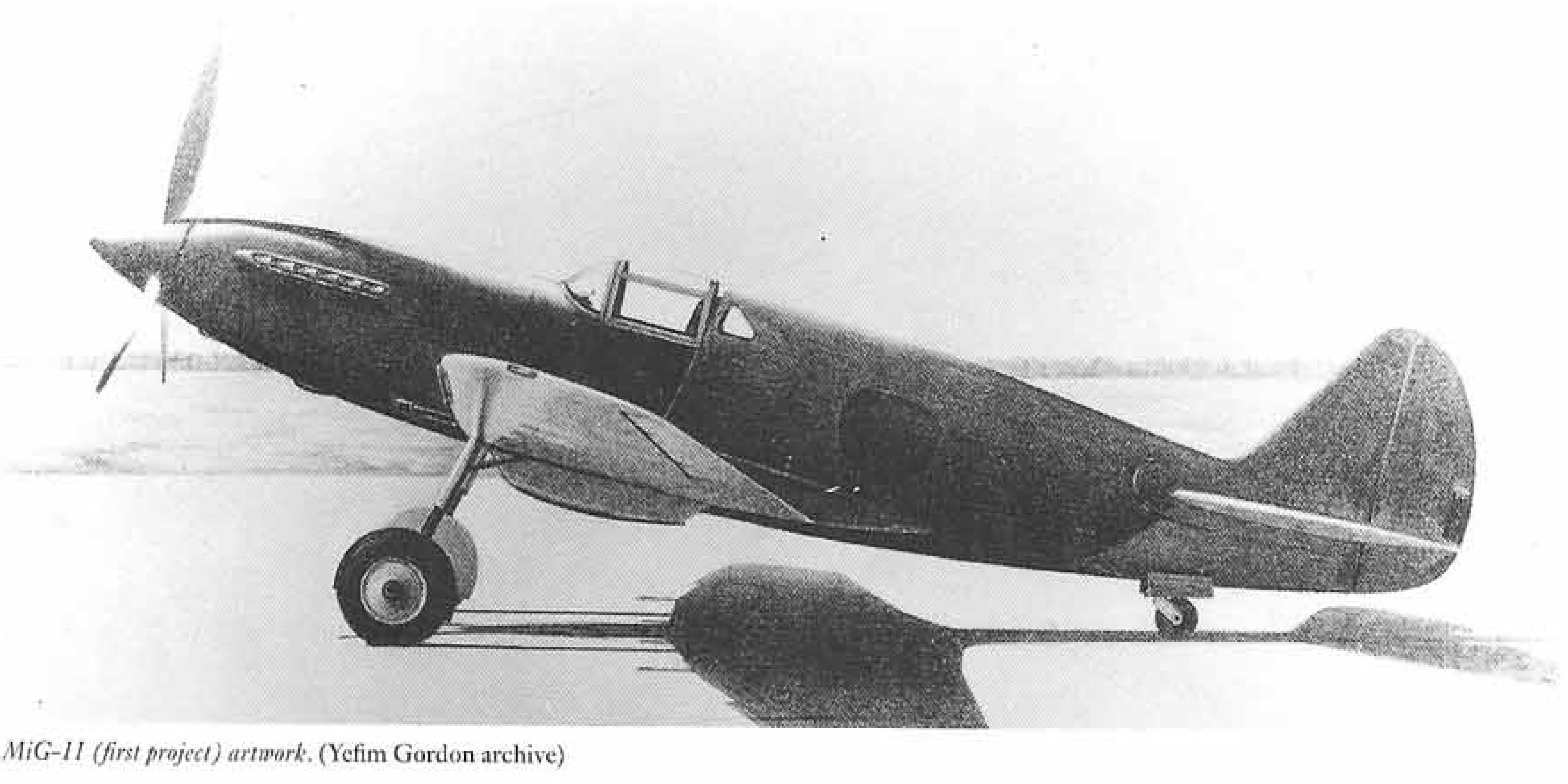
The result was a succession of some of the greatest high-altitude piston-engined fighters ever built. They were completely new designs, had Mikulin liquid-cooled V-12 engines, and to varying degrees retained mixed wood/metal construction, but were significantly larger than the previous MiG fighters, and had totally different engine cooling systems, landing gear and armament.

The first prototype was called A, and received NKAP designation I-220. Two prototypes were ordered, to be fitted with AM-39 engines, but I-220 No. 01 began its flight-test programme with the AM-38F, with a takeoff power of 1,700hp and maximum power of 1,500hp at the low full-throttle height of 4,800m (15,750ft), which was well suited to this engine's production application, the Il-2. Each cylinder had its own ejector exhaust stub, and the propeller was the three-blade AV-5A, with standard diameter of 3.6m (11ft 9¾in).

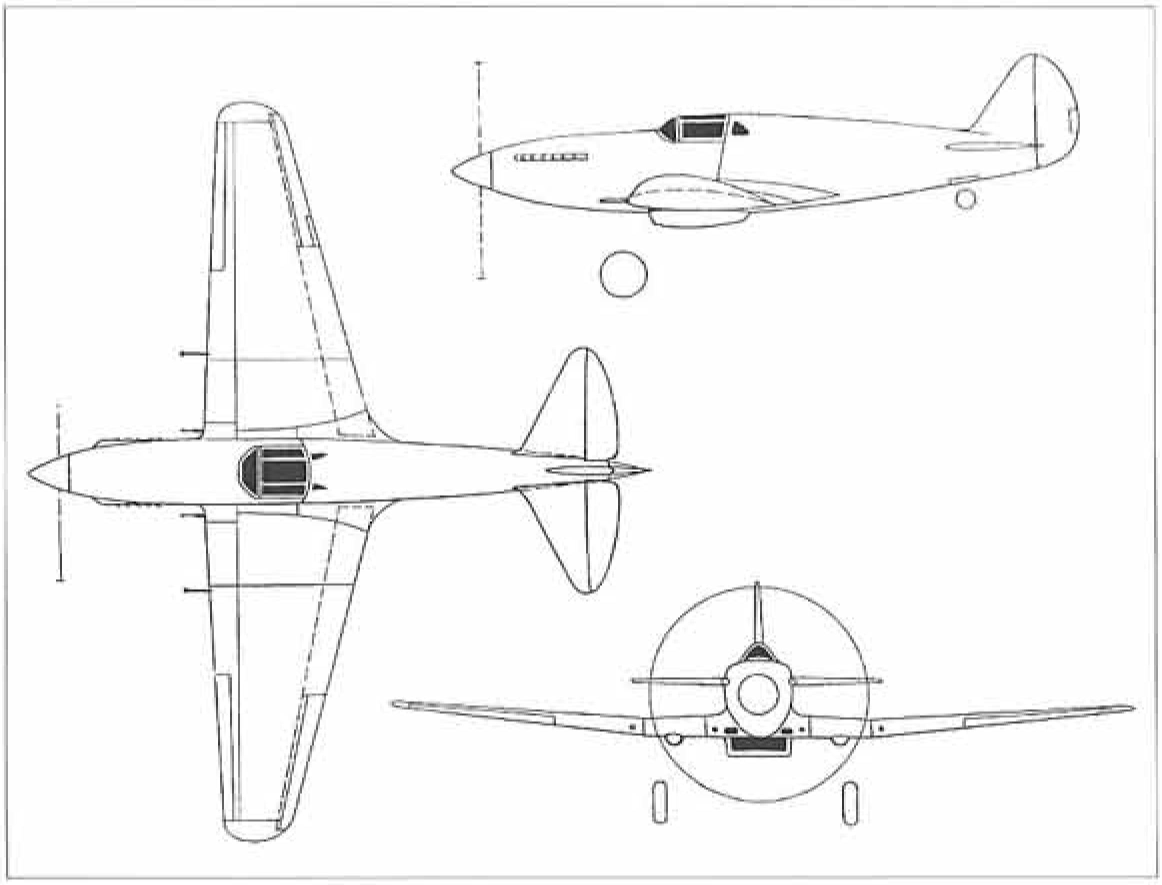
The fuselage was mainly of multi-layer *shpon* construction, with a steel-tube truss to carry the engine. The pilot was placed near the centre of gravity, ahead of the two fuselage fuel tanks. The tail was a light-alloy structure, bolted on to the fuselage longerons, generally similar to the tail of the I-230, with the tailplane mounted high but with its span increased from 3.66 to 3.75m (12ft 3⅝in). The wing was entirely new. Aerofoil profile was a CAHI laminar type, with the maximum thickness at about 40 per cent chord. The horizontal centre wing, with a span of 3.96m (13ft), was entirely of D16 light alloy except for the 30KhGSA booms of the main spar. This duralumin/steel spar was continued in the outer panels, but these were otherwise mainly of wood, apart from being fitted with full-length duralumin slats. Taper on the outer wings was entirely on the leading edge. Large split flaps were fitted to the centre wing and outer panels. It is believed that this and all derived prototypes were designed to an ultimate load factor of 8.

All air inlets were in the leading edge of the centre wing. At the roots were deep 'letterbox' intakes for the supercharger and for the two oil coolers. Outboard, extending to the end of the region in the propeller slipstream, were shallower inlets serving the very efficient box-type glycol radiators behind the main spar, with controllable exit flaps in the wing upper surface from 52 to 57 per cent chord.

Also novel was the main landing gear. Each unit comprised a main leg of high-strength steel, at the lower end of which was pivoted a forged link projecting ahead, parallel to the ground with the aircraft parked, carrying the wheel 350mm (13.8in) in front of the axis of the leg. A separate



MiG-11 (first project) artwork. (Yefim Gordon archive)



MiG-11 first project.

oleo shock strut was pin-jointed to the top of the leg and to the top of a ∩-frame holding the axle. This multiplied the stroke of the shock strut so that on rough ground vertical travel of the wheel could be 515mm (20.3in). Track was 3.652m (143.8in), and tyre size 650 × 200mm (the same as the MiG-3, despite the greater weight). Retraction inwards was pneumatic, the wheel bays being faired by flat doors hinged on the aircraft centreline. Cables retracted the tailwheel, which was of a new design, tyre size being 350 × 125mm.

Another innovation was that all fuel tanks were 'soft' bladders, made of rubberized fabric with a self-sealing coating. Despite the modest capacity there were six tanks, four small cells in the wings and two in the fuselage. The fuselage tanks were installed from below and supported on an aluminium 'cup' inside a container made of special fireproof plywood coated on both sides with chlorovinyl varnish. The broad cockpit was designed for eventual pressurization, but this was not fitted. The canopy slid directly to the rear. Like Curtiss fighters, the pilot had a limited rear view through the fixed aft canopy past the recessed plywood deck behind his seat. Inside this deck was the radio, served by a wire antenna direct to the fin.

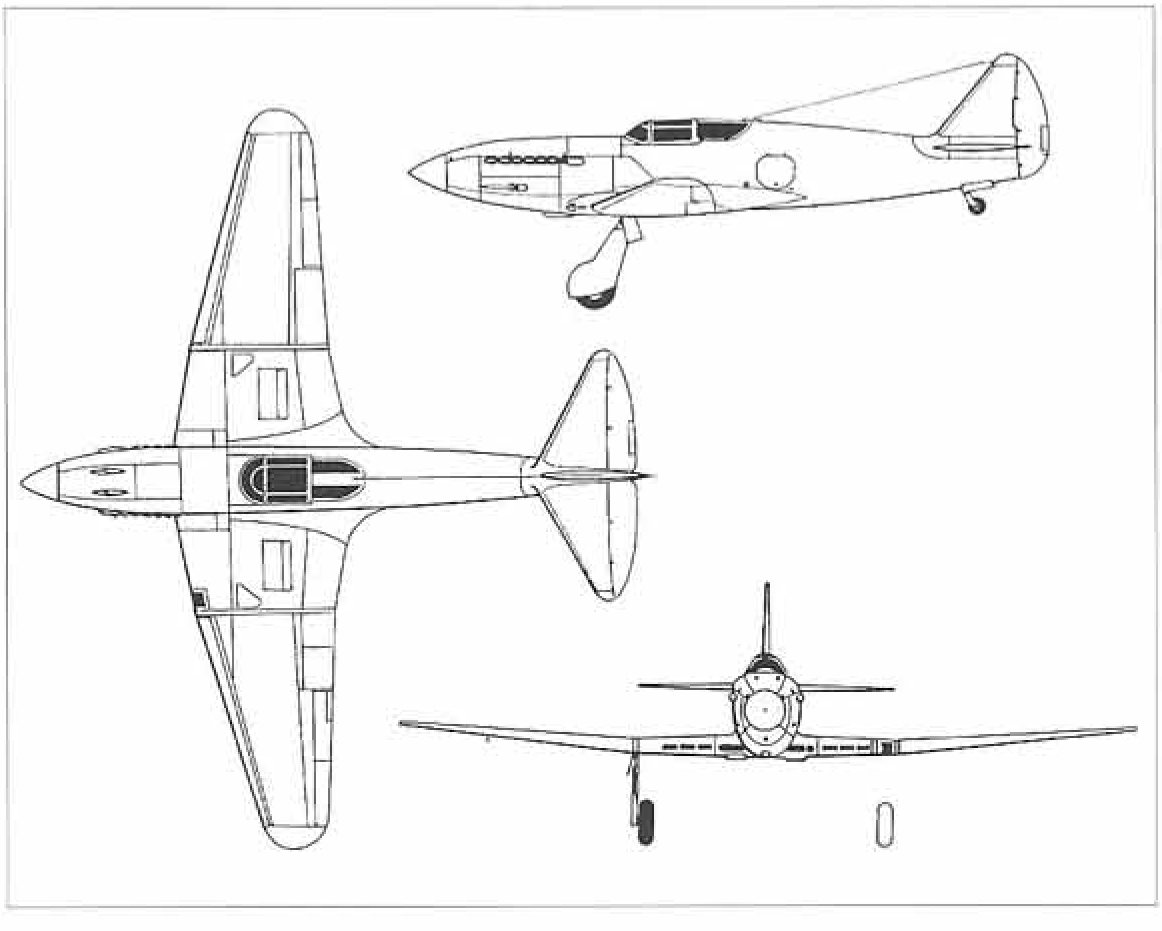
Reflecting combat experience, the intended armament was four 20mm ShVAK cannon, two above the engine and two beside the crankcase, each with 150 rounds. In fact, only the upper pair were actually installed. It is surprising that the lower blast tubes were not faired over.

Aircraft A No. 01 was painted in three-tone dark green/pale brown/pale grey camouflage, with white-bordered national markings. This aircraft was rolled out at Khodynka in June 1943. It was first flown in July 1943, the assigned pilot being A P Yakimov of the LII-NKAP. Later testing involved other pilots, including P A Zhuravlyov and I I Shelest. It proved to be an outstanding aircraft, marred only by the low-altitude rating of the engine. Had it gone into production the VVS would have allotted the next fighter (odd-number) designation, MiG-11.

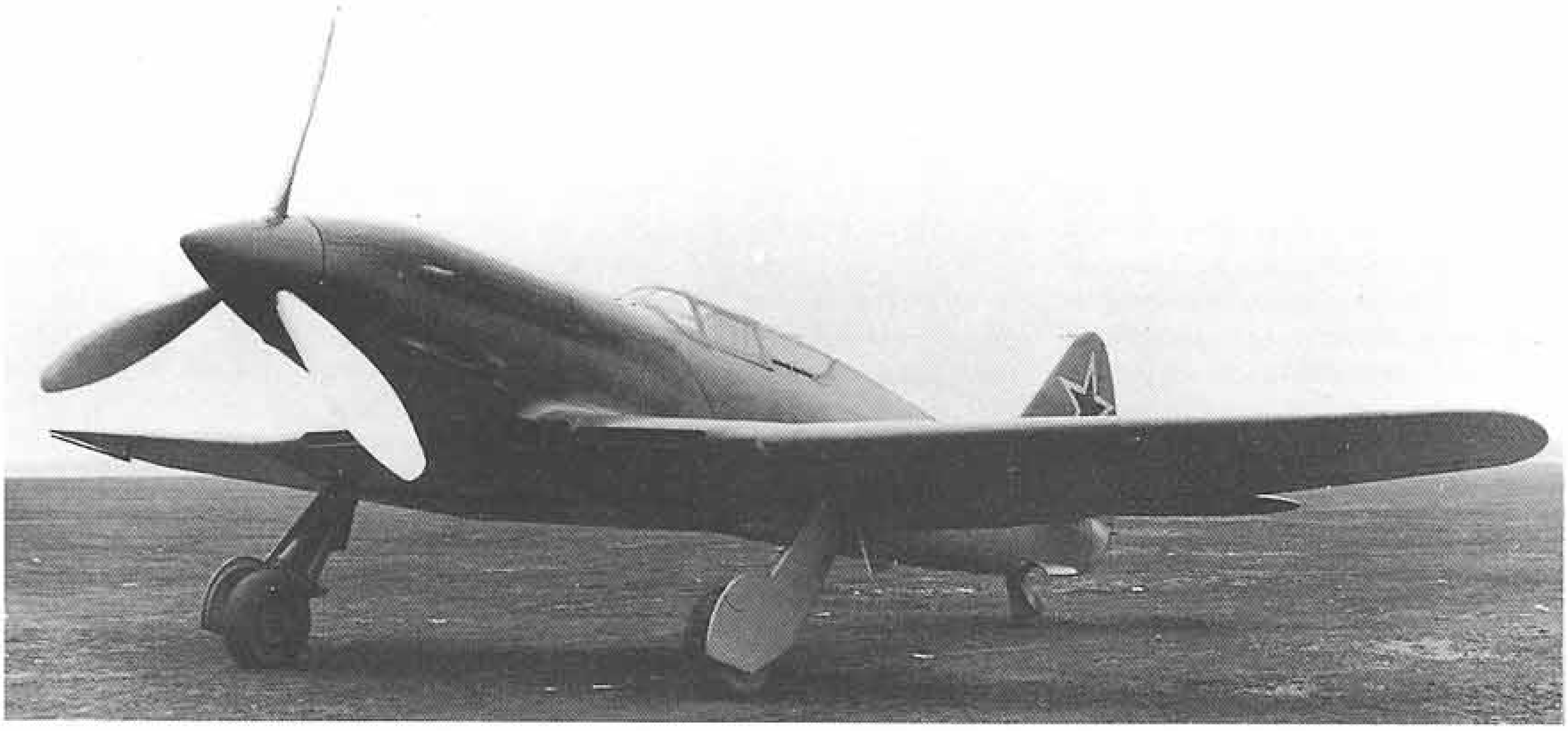
Aircraft A No. 02 was the first of these larger fighters to be powered by the AM-39 engine, with a takeoff rating of 1,800hp and maximum rating of 1,500hp at 7,100m (23,294ft). It had all four guns fitted, though with only 100 rounds each. It is believed to have been the first Soviet aircraft with a whip-type radio antenna, serving an RSI-4 radio behind the cockpit.

Aircraft No. 02 was rolled out in July 1943. Predictably, its empty weight was greater than that of the two-gun No. 01, but what is not explained is how No. 02's loaded weight could be lighter. Its factory flight-test programme in July–August 1943 was mainly in the hands of Shelest. Later many other pilots were involved, and NII-VVS testing took place between 14–24 July 1944. According to Shavrov, these were halted by engine failure. Among the criticisms were rather heavy elevator and aileron loads, difficulty of getting the landing gear to lock up and inadequate rearward visibility.

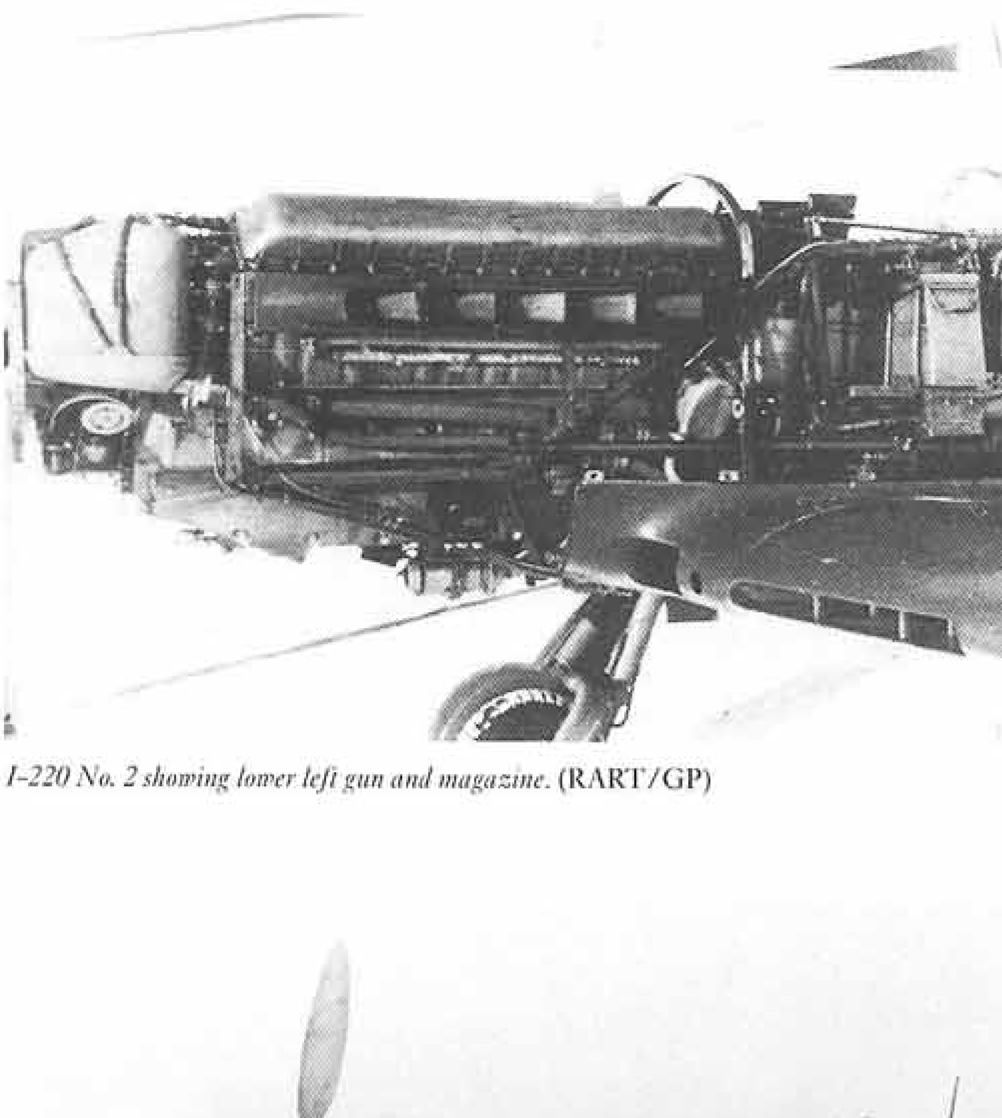
Meanwhile, aircraft No. 01 had been re-engined with the AM-39 and subjected to continued factory testing in January–August 1944. Long before this, the design staff had moved on to



I-220.



I-220 No. 1 (AM-38F). (OKB)



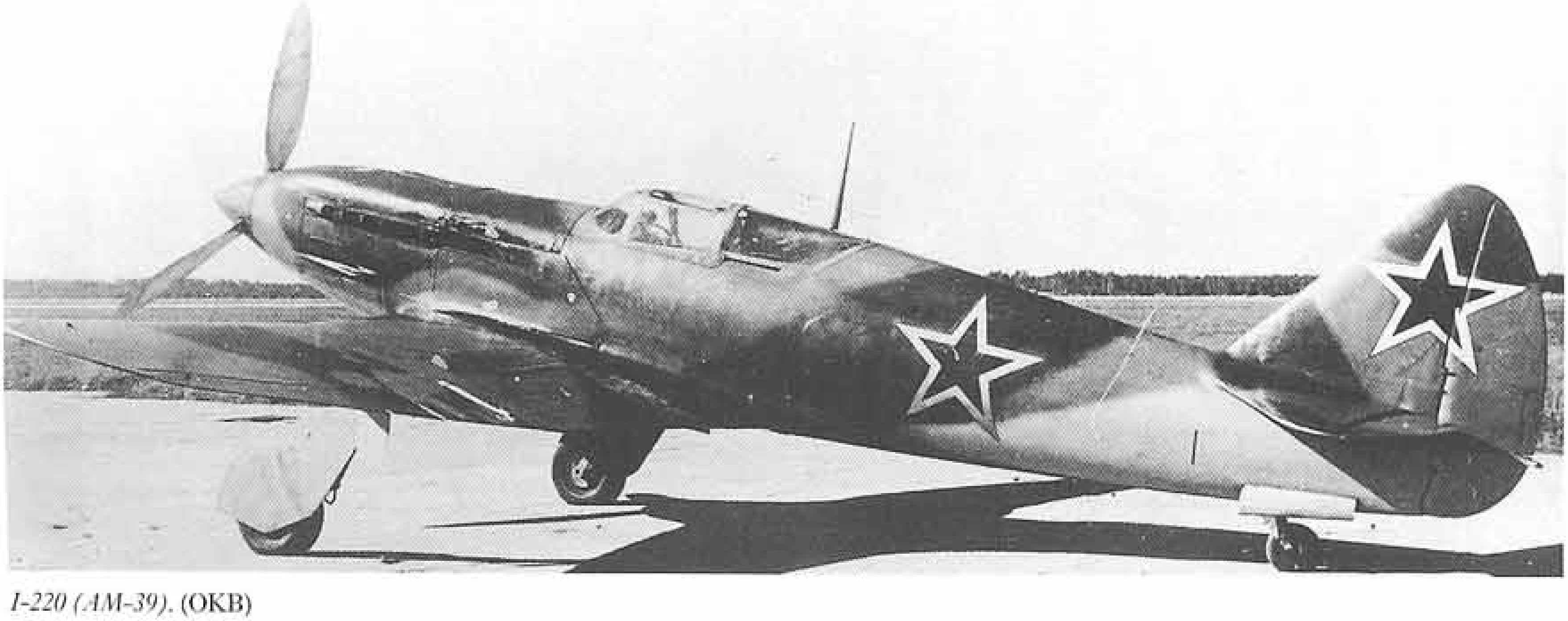
I-220 No. 2 showing lower left gun and magazine. (RART/GP)

produce developed versions of the same basic design. In the data below the figures in square brackets refer to I-220 No. 02.

Span 11m (36ft 1in); length 9.603m (31ft 6in); wing area 20.38sq m (219.38sq ft).

Weight empty (AM-38F) 2,936kg (6,473lb), (AM-39) 3,013kg (6,642lb) [3,101kg, 6,836lb]; fuel 335kg (738.5lb); oil 45kg (99lb); weight loaded (AM-38F) 3,574kg (7,879lb), (AM-39) 3,835kg (8,455lb) [3,647kg, 8,040lb].

Maximum speed (AM-38F) 572km/h (355mph) at sea level, 630km/h (391mph) at 7,000m (22,966ft), (AM-39) 550km/h (342mph) at sea level, 668km/h (415mph) at 7,000m [571km/h, 355mph, at sea level; 697km/h, 433mph, at 7,000m]; climb to 5,000m (16,404ft) (AM-38F) 4.6min [4.5min]; service ceiling (AM-38F) 9,500m (31,168ft) [11,000m, 36,090ft]; reported figures for range vary (AM-38F) 730–960km (454–597 miles) – (AM-39) 630–660km (391.5–410 miles); no figures for takeoff or landing.



I-220 (AM-39). (OKB)

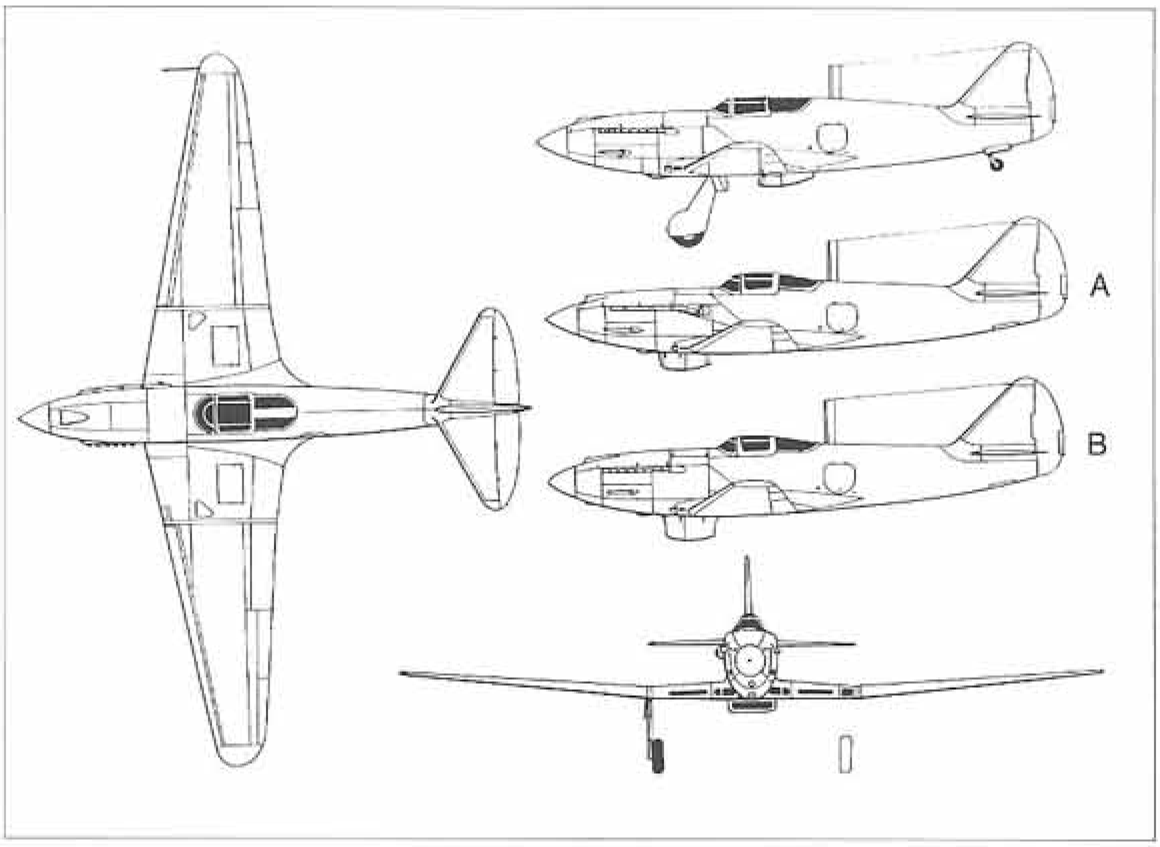
I-221, 2A, MiG-7

This second type of high-altitude interceptor was spurred by continued overflights in summer 1942 by Ju 86R aircraft at altitudes beyond the reach of Soviet aircraft. It incorporated important modifications intended to improve performance in the stratosphere. Only one 2A prototype was built, and a reliable description is difficult. No photographs of it have been discovered, and published descriptions contain obvious errors.

The engine was an AM-39A, a variant of the Mikulin family fitted only to this prototype and Polikarpov's ITP (M-2). Takeoff rating was 1,550hp, maximum power was 1,700hp reached at the full-throttle height of 5,200m (17,060ft), and both Shavrov and Belyakov state that two TK-2B turbosuperchargers enabled rated power (given by Shavrov as 1,400hp) to be maintained to the extraordinary height of 13,000m (42,650ft). The difficulty is that the OKB drawing shows a TK-2B on the right (starboard) side only. The drawing also shows that the propeller had three blades, and was probably an AV-5A.

One feature about which there is no confusion is that the wing was completely redesigned. Section profile was NACA-234, a so-called laminar aerofoil, with thickness/chord ratio of 14 per cent at the root and 10 per cent at the tip. The outer wings were redesigned as all-metal structures, with increased span, and with the aerodynamic centre moved forwards by reducing taper on the leading edge and increasing it on the trailing edge. As before, each outer wing had a full-span slat.

The rear fuselage (where this joined the centre fuselage is not known) was redesigned as a light-alloy stressed-skin structure integral with the fin. For the first time in a MiG aircraft, the cockpit, part of the (presumably) laminated-wood centre fuselage, was pressurized. The design was based on that developed for earlier fighters by A Ya Shcherbakov, with inflatable seals and hot-air demisting. It was also air conditioned, cooling being provided by a heat exchanger in a duct under the fuselage, but this radiator was probably mainly an intercooler for the engine charge air (*see* I-222, 3A). The centre-wing glycol radiators were unaltered. From the data it is clear that fuel capacity was increased, but details are unknown.



Three views of I-221 (A: I-222; B: I-224).

Shavrov states that the mainwheels were moved forwards, but the drawing denies this. The drawing also gives the track as 3,516mm (138.4in), though how this was changed from the previous 3,652mm is not known. Armament comprised two 20mm ShVAK beside the engine, each with 150 rounds, the upper pair being omitted. Zhuravlyev began the flight-test programme on 2 December 1943, and Yakimov of the LII-NKAP also flew this aircraft.

Different books state that 'company flight development was not completed', 'Zhuravlyev … did not know that the flames issuing from the supercharger were a normal phenomenon … and parachuted to safety', and 'a valve push-rod broke … the pilot had to bail out'. What actually happened was that the I-221 was damaged beyond economic repair in a wheels-up landing.

Span 13m (42ft 7¾in); length 9.55m (31ft 4in); wing area 22.44sq m (241.5sq ft).

Weight empty 3,179kg (7,008lb); fuel 448kg (987.7lb); oil 40kg (88lb); weight loaded 3,888kg (8,571lb).

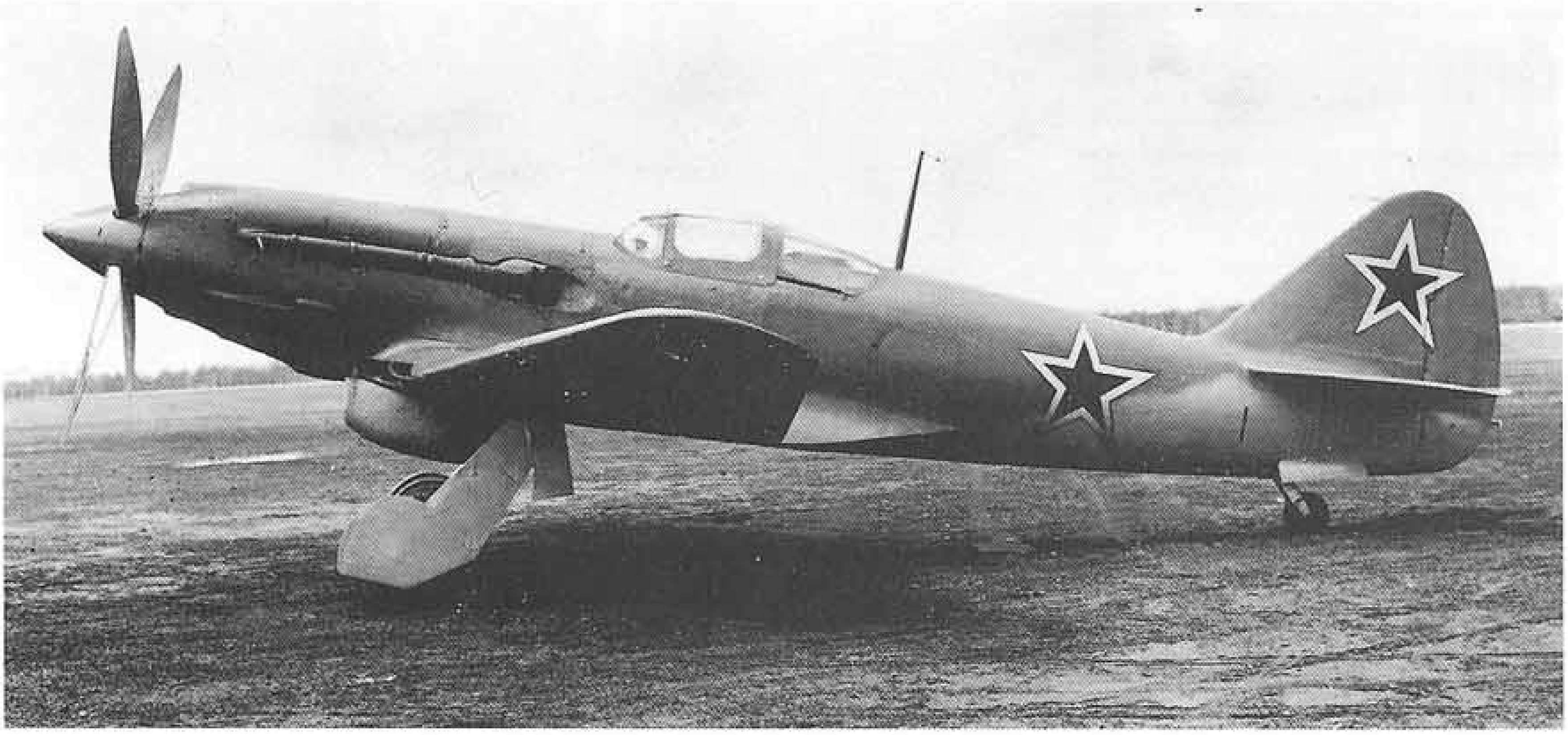
Maximum speed (estimated) 600km/h (373mph) at sea level, 689km/h (428mph) at 7,000m (22,966ft); climb to 5,000m (16,404ft) 4.6min; service ceiling (estimated) 14,500m (47,570ft); no other data.

I-222, 3A, MiG-7

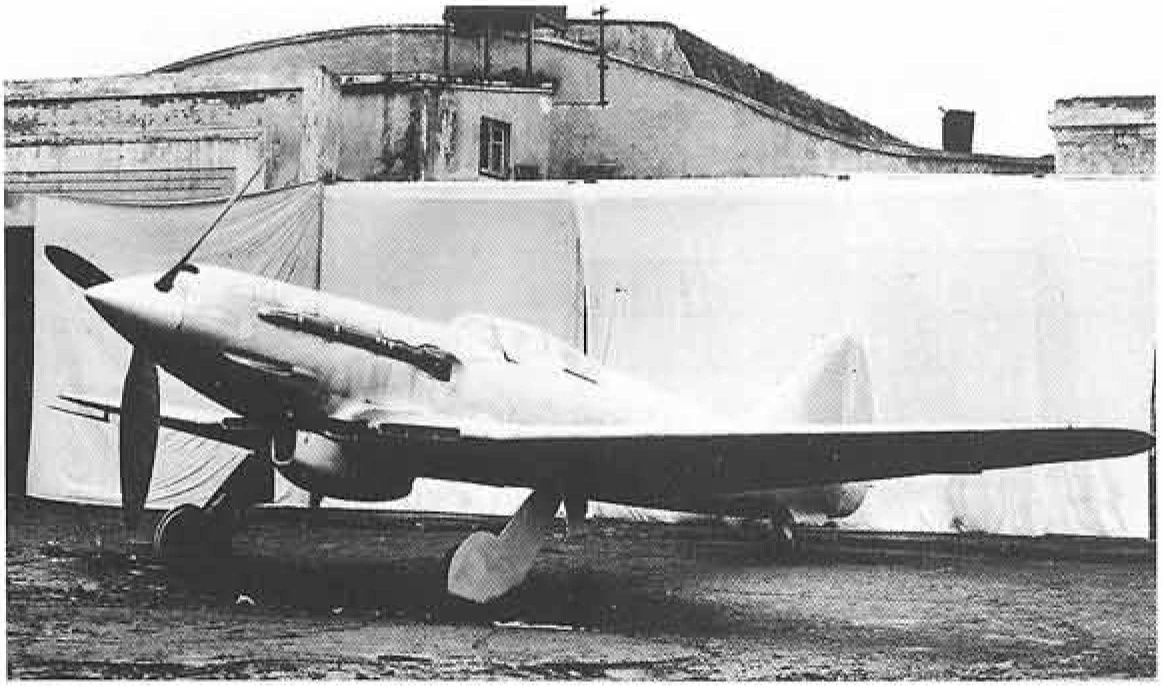
The third type of A-series interceptor had the greatest high-altitude performance of all, though for level speed (at lower altitudes) it was beaten by other versions. The engine was an AM-39B-1, with a single TK-300B turbosupercharger on the left side. This was the highest-capacity turbo developed at CIAM (Central Institute of Aviation Motors) at that time, and it enabled the standard-size (46.6lit) engine to have a takeoff power of 1,860hp, and maximum ratings of 1,620hp at 6,500m (21,325ft) and the amazing output of 1,430hp at 13,200m (43,307ft). An intercooler was added to cool the incoming charge air after it had passed through the turbosupercharger but before entering the gear-driven supercharger on the engine. This heat exchanger was mounted in a deep but narrow duct under the leading edge.

Dry engine weight was 1,043kg (2,299lb), the turbo weighed 85kg (187lb), the radiators and coolant 128kg (282lb), the heat exchanger 80kg (176lb), the oil coolers and lubricant 65kg (143lb), coolant and oil piping 12kg (26.5lb), the exhaust pipes 23kg (50.7lb) and the steel-tube engine mounts 30kg (66lb).

The airframe was similar to that of the I-221, with some important changes. Except for the slats, the



I-222 with AV-9L-26 propeller. (RART)



I-222 as built. (RART)

long-span outer wings reverted to wooden construction. The rear fuselage also reverted to wooden construction, and its top line was lowered, so that the new aft section of canopy gave a better view to the rear. Both the vertical and horizontal tails were enlarged, the former to 2.01sq m (21.6sq ft) and the latter to 3.34sq m (35.95sq ft).

The cockpit was again pressurized and air conditioned, the engine intercooler also serving as cockpit heat exchanger. Unlike its predecessors the 3A was fitted with a 64mm (2½in) bulletproof windscreen, bulletproof glass of the same thickness behind the pilot's head and pressure bulkheads of 8mm or 9mm armour plate. Unlike the I-221/2A the sliding canopy had a heavy metal frame which noticeably reduced the pilot's field of view. Fuel capacity was reduced by eliminating fuselage cells, and the single oil tank was mounted in the leading edge and armoured. Armament comprised only the two lower ShVAK, with magazines reduced to 80 rounds each. The radio had a rigid mast and wire antenna.

The 3A was rolled out on 23 April 1944. It was unpainted, and fitted with an AV-5A three-blade propeller. In this form it was flown by A I Zhukov (not Yakimov, as often reported) on 7 May. It demonstrated the highest service ceiling of any Allied piston-engined fighter. Shortly afterwards the aircraft was painted, and fitted with an AV-9L-26 four-blade propeller, of 3.6m (11ft 9¾in) diameter, which was installed when the following data were measured. By 1944 the need for such aircraft was considered no longer urgent, and the intended VVS designation of MiG-7 was never used.

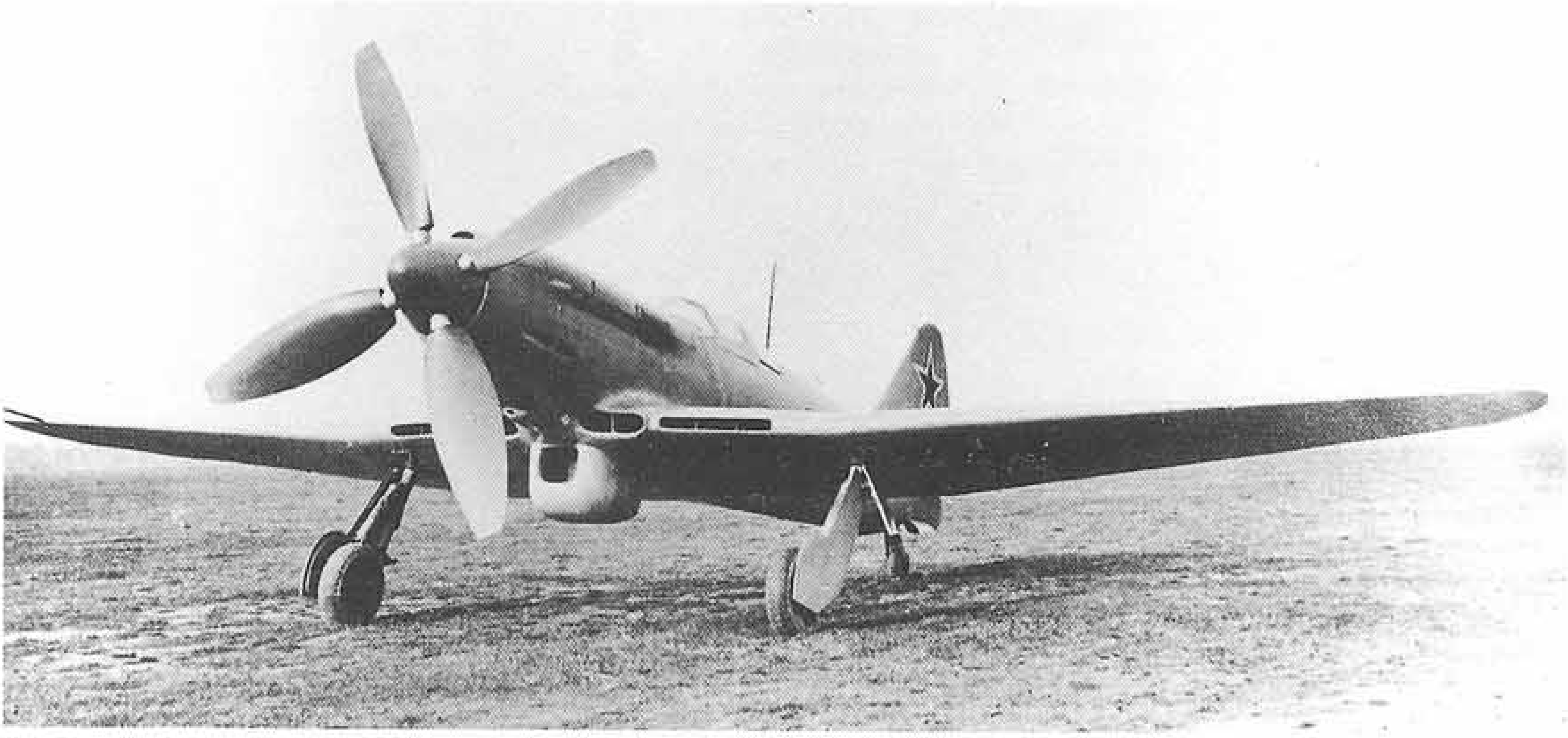
Dimensions as I-221, 2A, except length 9.603m (31ft 6in).

Weight empty 3,167kg (6,982lb); fuel 300kg (661lb); oil 40kg (88lb); weight loaded 3,790kg (8,355lb).

Maximum speed 599km/h (372mph) at sea level, 682km/h (424mph) at 6,700m (21,982ft), 691km/h (429.3mph) at 12,500m (41,010ft); climb to 5,000m (16,404ft) 4.6min; service ceiling (estimated) 14,500m (47,572ft); range (estimated) 700km (435 miles); landing speed 169km/h (105mph).

I-224, 4A, MiG-7

In most respects this experimental prototype was similar to its immediate predecessor. Significant changes were: the TK-300B turbosupercharger was moved to the right side; the pressurized cockpit was of welded aluminium alloy (possibly a world 'first') and pressurized to 0.3kg/sq cm (4.3lb/sq in) by a bleed from the engine's gear-driven supercharger; the propeller was the AV-9L-22B of 3.5m (11ft 5¾in) diameter, with four so-called 'paddle' blades of 0.4m (15.75in) chord; fuel capacity was considerably increased, from 422 to 670 litres (147.5gal); the centreline heat exchanger was made noticeably deeper; the main glycol radiators in the centre wing were given twin 'sitting dog' controllable exit ducts, projecting promi-



I-224. (OKB)

nently above the wing; and the gun magazines were enlarged to 100 rounds.

Aircraft 4A was rolled out in September 1944, apparently painted dark grey above and pale grey below. Yakimov began the flight-test programme on 20 October. No explanation has been forthcoming why, weighing slightly more than its immediate predecessor, it should be faster, nor why the service ceiling should have been so much inferior and the range, though increased, should have fallen 400km below estimates. Unfortunately Yakimov had to abandon the aircraft when supercharger disintegration led to uncontrollable engine fire.

Dimensions, as 2A, 3A, except length 9.51m (31ft 2⅜in)

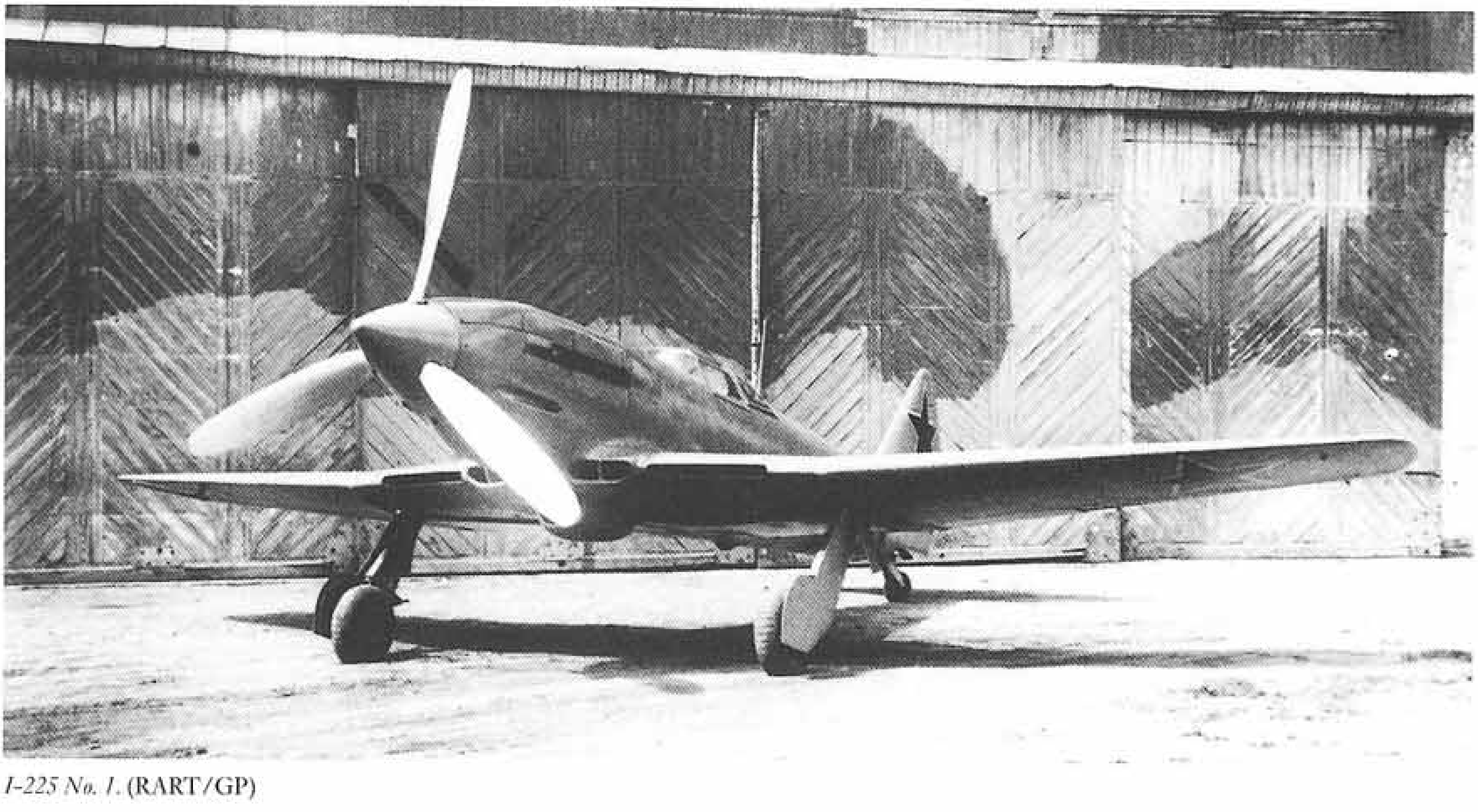
Weight empty 3,105kg (6,845lb); fuel 476kg (1,049lb); oil 45kg (99lb); normal loaded weight 3,780kg (8,333lb); maximum loaded weight 3,921kg (8,644lb).

Maximum speed 601km/h (373.5mph) at sea level (estimated), 693km/h (431mph) at 13,000m (42,651ft); climb to 5,000m (16,404ft) 4.8min; service ceiling 14,100m (46,260ft); range 1,000km (621 miles); takeoff run 230m (755ft); landing speed 127km/h (79mph); landing run 440 m (1,444ft).

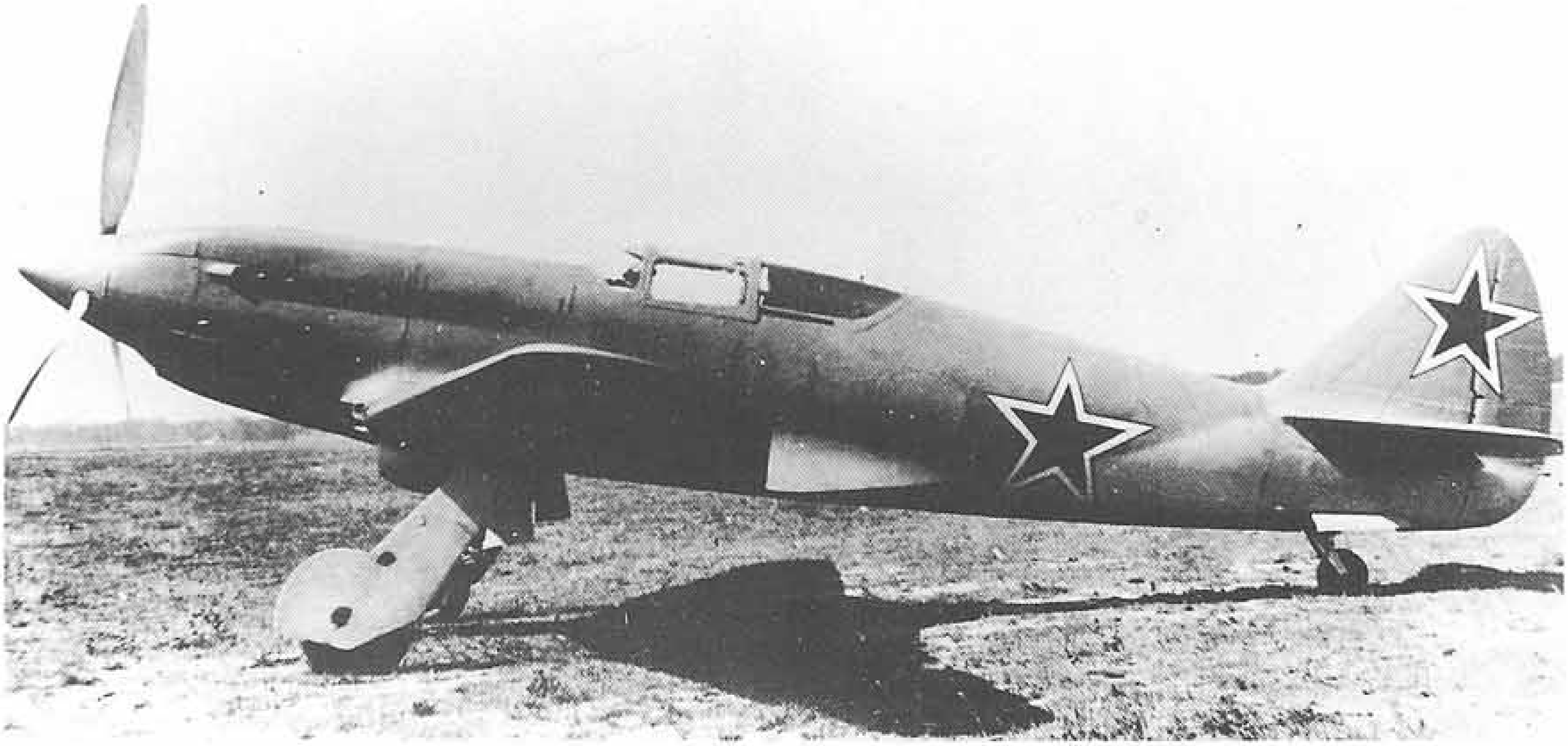
I-225, 5A

Aircraft 5A was the last of the wartime MiG fighter designs. It was also the heaviest, most powerful and fastest. Unlike its predecessors, it was not specifically intended for fighting at extreme altitudes, but because of its very powerful engine its climb and service ceiling were superior to rival fighters.

Under project manager Anatoliy G Brunov, the 5A was based on the



I-225 No. 1. (RART/GP)



I-225 No. 2. (Yefim Gordon archive)

original A, type I-220, even retaining the small tail. The principal differences were a refined and stronger structure, with all-metal outer wings, and a welded pressurized cockpit. The engine was Mikulin's AM-42B, cleared to increased rpm than the AM-39 family, with a single TK-300B turbosupercharger on the right side. Takeoff power was 2,000hp, and maximum power at both rated altitude and at full throttle at 7,500m (24,606ft) was 1,750hp. The propeller was the three-blade AV-5A-22V of 3.6m (11ft 9¾in) diameter. The underside of the cowling was deeper than before, but the reduced high-altitude demand meant that the ventral heat exchanger could be much smaller.

Though pressurized, the cockpit had a narrow-frame canopy similar to that of the unpressurized A and 2A, giving a significantly better field of view. Equipment included improved instruments and controls, and a new radio (described as ultrashort-wave, meaning vhf, though served by a wire antenna). Protection included a 64mm windscreen and rear glass slab, and 9mm seat armour. Armament reverted to four ShVAK, two above the engine and two beside the crankcase, each with 100 rounds.

A single 5A aircraft was ordered, with NKAP designation I-225. No VVS designation was allotted, because there was never a serious chance of this aircraft being placed in production. It appears to have had the two-tone grey camouflage. It was first flown by Yakimov on 21 July 1944. Trouble must have been conspicuously absent, because only two days later it took off on its fifteenth flight. Unfortunately, on this flight the engine failed at a height of some 15m (49ft), and the 5A No. 01 was damaged beyond repair.

Surprisingly, a second prototype was ordered. This aircraft, 5A No. 02, was fitted with the AM-42FB engine, with a takeoff and combat power of 2,200hp. Documents state that pilot field of view was improved. It was put through a fairly brief factory test programme, beginning on 14 March 1945. Its level speed proved to be the second-fastest of any Soviet piston-engined (nonjet-assisted) aircraft, beaten only by the much smaller Yak-3/VK-108. It also demonstrated exceptional range. Data are for 5A No. 02.

Span 11m (36ft 1in); length 9.51m (31ft 2½in) or 9.603m (31ft 6in); wing area 20.38sq m (219.38sq ft).

Weight empty 3,010kg (6,636lb); fuel 350kg (772lb); oil 41kg (90.4lb); weight loaded 3,900kg (8,598lb).

Maximum speed 617km/h (383mph) at sea level, 720km/h (447mph) at 8,500m (27,887ft); climb to 5,000m (16,404ft) 4.5min, to 10,000m (32,808ft) 8.8min; service ceiling 12,600m (41,340ft); range 1,300km (808 miles); takeoff distance 257m (843ft); landing speed 134km/h (83.3mph); landing run 450m (1,476ft).

The aircraft length cannot be confirmed.

I-250, N

Together with the very similar Sukhoi Su-5, this unusual little fighter was designed in great haste to meet the challenge of German jet and rocket aircraft. Existence of such aircraft became known in the winter of 1943–44, and in the first week of 1944 Britain and the USA announced that they too were flying jet aircraft. Two weeks later the GKO, the State Committee for Defence, ordered Lavochkin, Mikoyan, Sukhoi and Yakovlev to build jet aircraft. Stalin criticized designers for not having jet aircraft already.

Arkhip Lyul'ka was in fact testing his VRD-2 turbojet, but it was nowhere near ready for use. The only available kind of jet powerplant was the VRDK, translated as air reaction auxiliary compressor. Developed since 1942 at the Central Institute of Aviation Motors by a team led by K V Kholshchevnikov, it comprised a conventional piston engine and propeller plus a shaft-driven auxiliary compressor, combustion chamber and jetpipe. Thus, an aircraft fitted with it was basically a traditional fighter, but with an additional jet boost system.

The engine was a Klimov VK-107R. This was basically a VK-107A, rated at 1,650hp for takeoff and at

1,450hp at 3,800m (12,470ft), but fitted with an auxiliary drive. At takeoff more than 95 per cent of the power was transmitted by the engine's reduction gear to the 3.1m (10ft 2in) AV-5B propeller. For a dash at maximum speed a clutch behind the crankshaft was engaged, driving a step-up gearbox (13 : 21 ratio) to a shaft which drove the auxiliary axial compressor in a large duct along the lower part of the fuselage. Air flowed through this duct at all times, from an inlet under the spinner, to cool the main radiator which was just behind the compressor. From the top of the duct a secondary pipe led to the supercharger on the engine. With the compressor under power the flow was greatly enhanced, the greater pressure in the secondary upper pipe serving to boost the output of the engine.

To energize flow through the main duct still further, petrol was sprayed from seven nozzles downstream of the radiator and ignited by sparking plugs. From this point the duct expanded to form a combustion chamber, its material changing from aluminium to welded stainless steel. Water from a 78lit (17gal) tank was sprayed over the duct to reduce wall temperature and protect the fuselage, the steam adding to the propulsive thrust. The high-velocity jet escaped through hydraulically controlled nozzle eyelids, which in cruising flight could fair over the nozzle to reduce base drag.

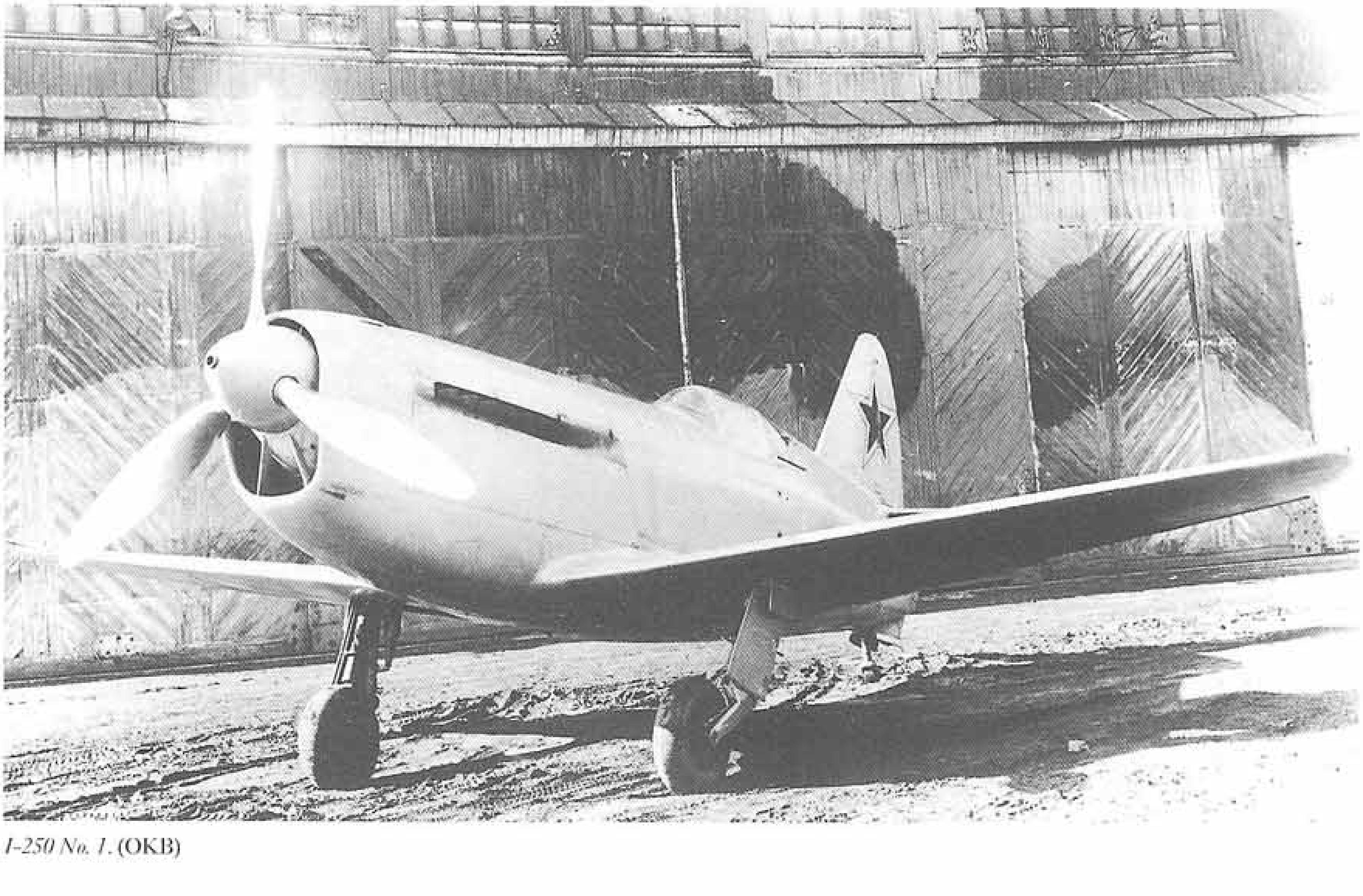
The whole system was clumsy, but in the absence of a turbojet an impressive achievement. At 7,000m (22,966ft) it was estimated to have an equivalent power of 2,500hp, of which 1,350 came from the auxiliary duct system. The VRDK had been extensively tested on the ground, but could not be flight tested until a Mikoyan or Sukhoi fighter could be completed. In the event, the MiG was ready first.

Aircraft N was of entirely stressed-skin construction, with no wood and with welded steel tubing restricted to the cradle carrying the engine. The wing had a 10 per cent CAHI laminar aerofoil, with two spars and plate ribs. CAHI slotted flaps were fitted, and two-section Frise-type ailerons outboard, but no slats. The fuselage comprised the engine compartment with removable cowl panels, the mid-section including the cockpit, and the short tail section to which was attached the removable tail unit. Because of the VRDK duct it looked exceptionally deep. Air rammed in around the top and sides of the spinner passed through the oil cooler around the propeller gearbox, exiting through controllable gills round the top of the cowling. Fuel was housed in a 415lit (91.3gal) fuselage tank and two 100lit (22gal) wing tanks, all of self-sealing rubberized fabric.

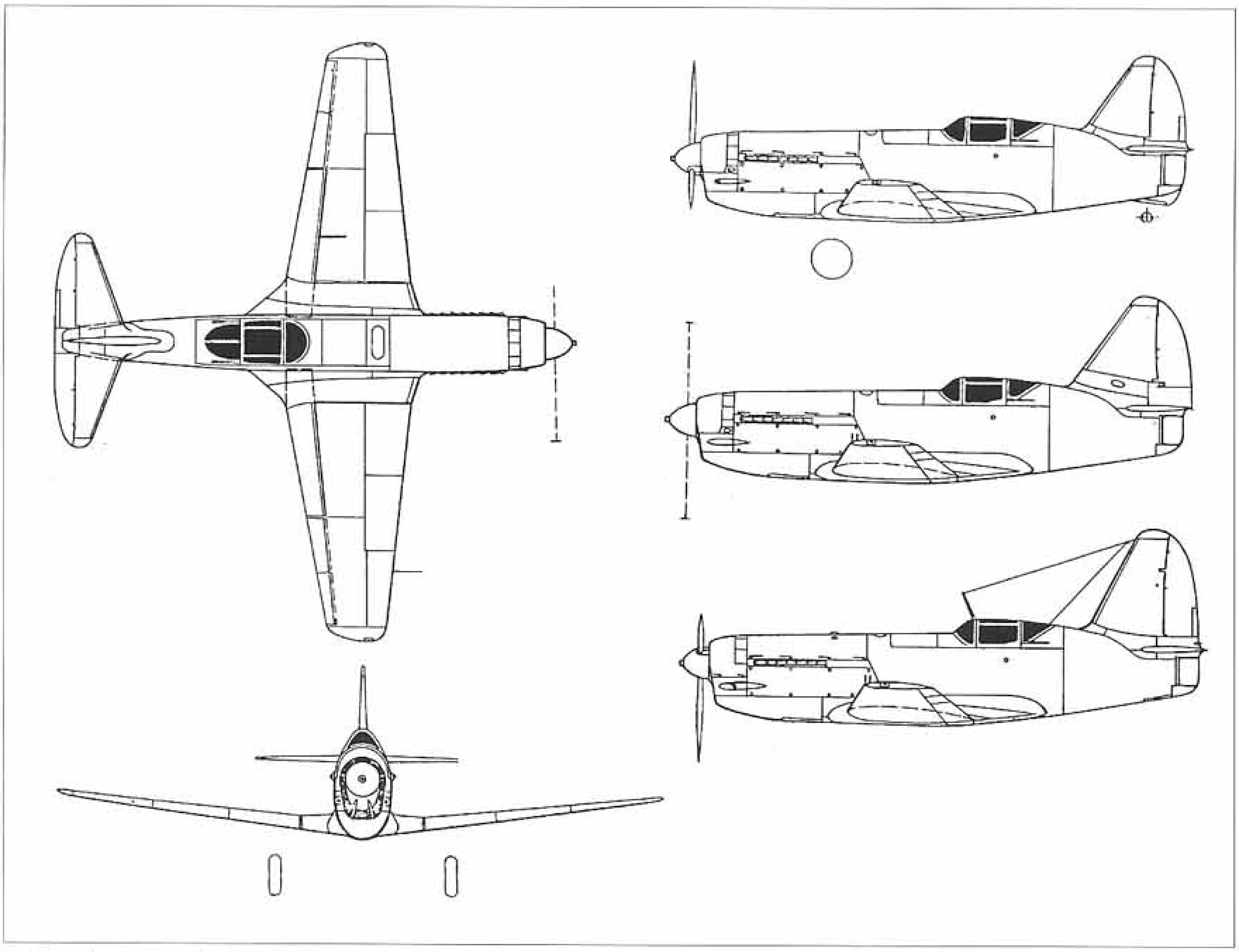
The main landing gear was most unusual in that the levered-suspension arms carrying the wheels were ahead of the legs. The bay doors were claimed by Mikoyan to be the first in the USSR to be closed at all times except when the gear was actually cycling up or down. Track was 2.75m (9ft ¼in) and wheelbase 4.995m (16ft 4⅔in). The small castoring tailwheel retracted into a fairing under the jet nozzle. Because of the big tank on the centre of gravity the cockpit reverted to its location in the first MiG fighters, behind the wing. The simple tail was entirely of stressed-skin construction, the port elevator having a trim tab.

A detailed mock-up was approved on 26 October 1944. The prototype, called the N No. 1, was rolled out on 26 February 1945, painted white. It was fully armed, with three ShVAK B-20 (not G-20) 20mm cannon, one firing through the propeller hub and the others beside the crankcase. Each magazine was from the outset designed to accommodate 160 rounds.

OKB pilot A P Deyev made the first flight on 3 March 1945. The AV-5L



I-250 No. 1. (OKB)



I-250, N No. 1 (centre right N No. 2, bottom right MiG-13).

was the standard VK-107 propeller used with success on many other aircraft. With the VRDK in operation the aircraft was extremely noisy, but said to be 100km/h faster than other piston-engined fighters. In mid-May Deyev pulled excessive g and was killed following tailplane failure.

The second prototype, N No. 2, flew in late May. It was painted dark blue, with a yellow horizontal streak, and at first had no guns fitted. LII pilot A P Yakimov was later assisted by OKB pilots A N Chernoburov and I T Ivashchenko. It was soon established that directional stability was inadequate, and the leading edge of the fin was reconstructed to increase chord. The tailwheel strut was redesigned, eliminating the need for the ventral fairing. This aircraft was damaged beyond repair in a crash landing by Chernoburov.

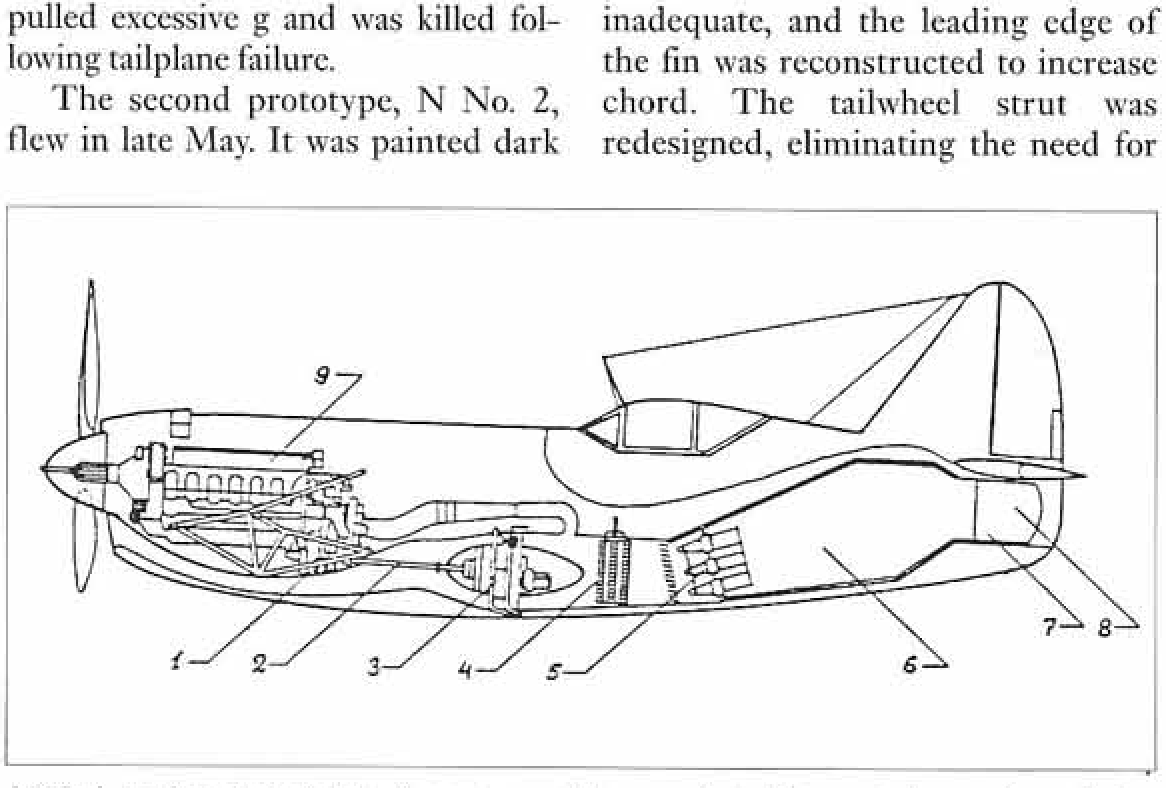
In June 1945 the OKB embarked on a crash programme to build ten aircraft for a flypast over Red Square on October Revolution day (7 November). The aircraft were built, and made deafening low-level practice runs with VRDK, but the actual air parade was cancelled by bad weather.

In the performance figures here, the use of VRDK is assumed. It was normally restricted to periods totalling ten minutes in any flight.

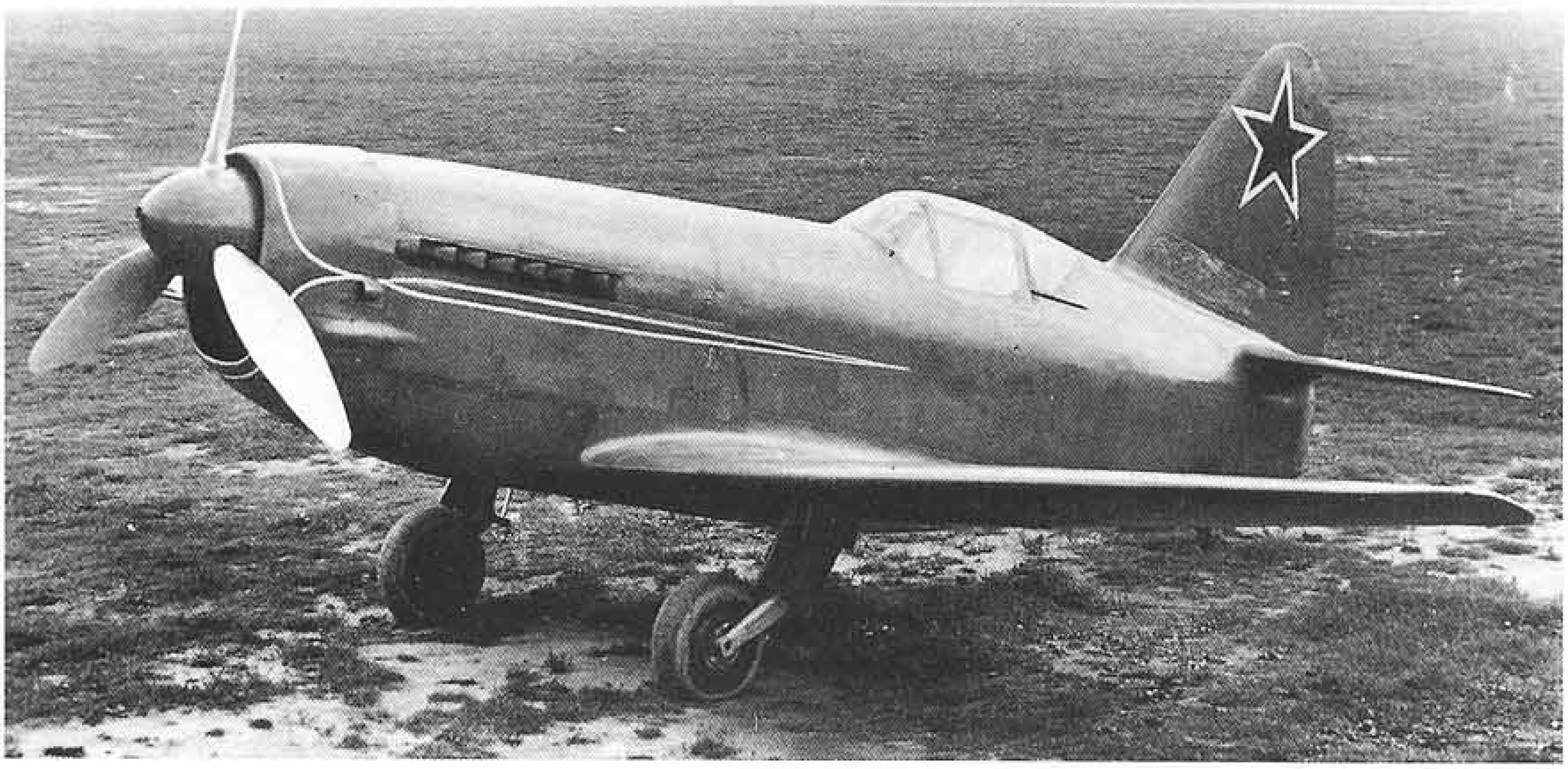
Span 9.5m (31ft 2in); length 8.185m (26ft 10¼in); wing area 15sq m (161.5sq ft).

Weight empty 2,587kg (5,703lb); fuel 450kg (992lb); oil 80kg (176lb); cooling water 75kg (165lb); weight loaded 3,680kg (8,113lb).

Maximum speed 620km/h (385mph) at sea level, 825km/h (513mph) at 7,000m (22,966ft); climb to 5,000m (16,404ft) 3.9min; service ceiling 11,960m (39,240ft) [without VRDK, 10,500m (34,450ft)]; range 920km (572 miles) [without VRDK, 1,380km (858 miles)]; takeoff run 400m (1,312ft); landing speed 150km/h (93mph); landing run 515m (1,690ft).



I-250: 1, gearbox; 2, shaft drive; 3, compressor; 4, honeycomb straightener; 5, burners; 6, combustion chamber; 7, nozzle flap; 8, nozzle; 9, VK-107R engine.



I-250 No. 2. (OKB)

MiG-13

In late 1946 the A-VMF, naval aviation, placed an order on Factory No. 381 for sixteen I-250s, with small modifications. A visible change was the curious use of slightly curved 'sabre' propeller blades; these were later replaced by standard AV-5B blades. Other changes, compared with I-250 N-2, included an increase in the height of the fin and rudder, an increase in the size of the two wing fuel tanks and the water tank, and the addition of RSI-4 radio with a wire antenna from the radio bay behind the head armour to the top of the fin and thence forwards to an unusual mast projecting diagonally forwards from the top of the windscreen frame.

Factory testing was completed in July 1947, and Ivan M Sukhomlin undertook NII-VVS testing between 9 October 1947 and 8 April 1948. These aircraft, with Service designation MiG-13, were delivered to the Baltic Fleet base at Skultye, near Riga, Latvia. The MiG-13 served in both the Baltic and Northern fleets until 1950.

Dimensions unchanged.

Weight empty 3,028kg (6,675lb); fuel 590kg (1,301lb); oil 80kg (176lb) as before; water 78kg (172lb); weight loaded 3,931kg (8,666lb).

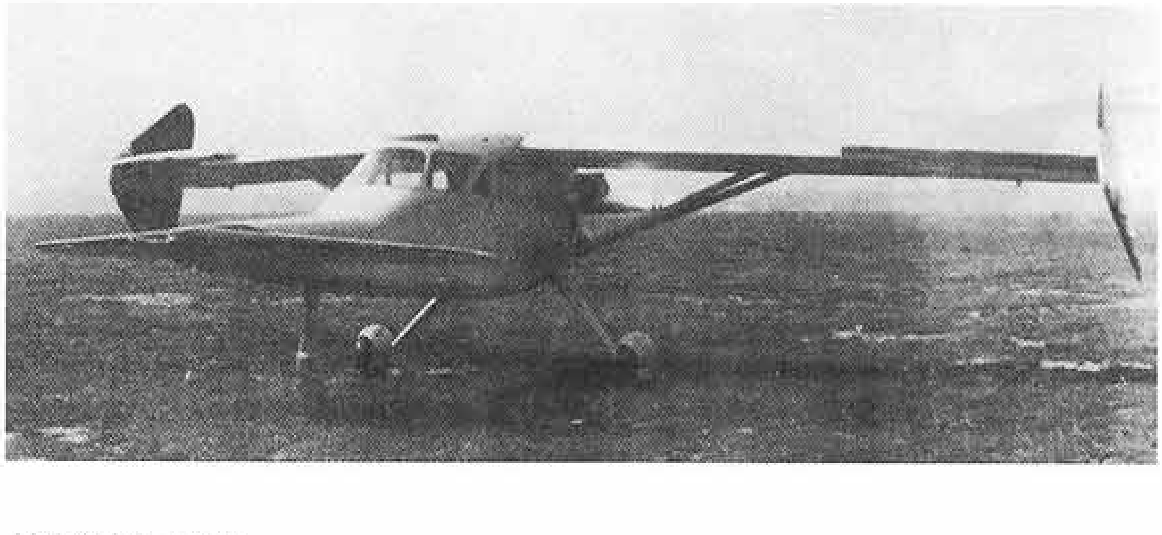
Performance similar to I-250 except: range (at 600km/h, 373mph, without VRDK) 1,818km (1,130 miles); takeoff speed 200km/h (124mph); landing speed 195km/h (121mph).

MiG-8, *Utka*

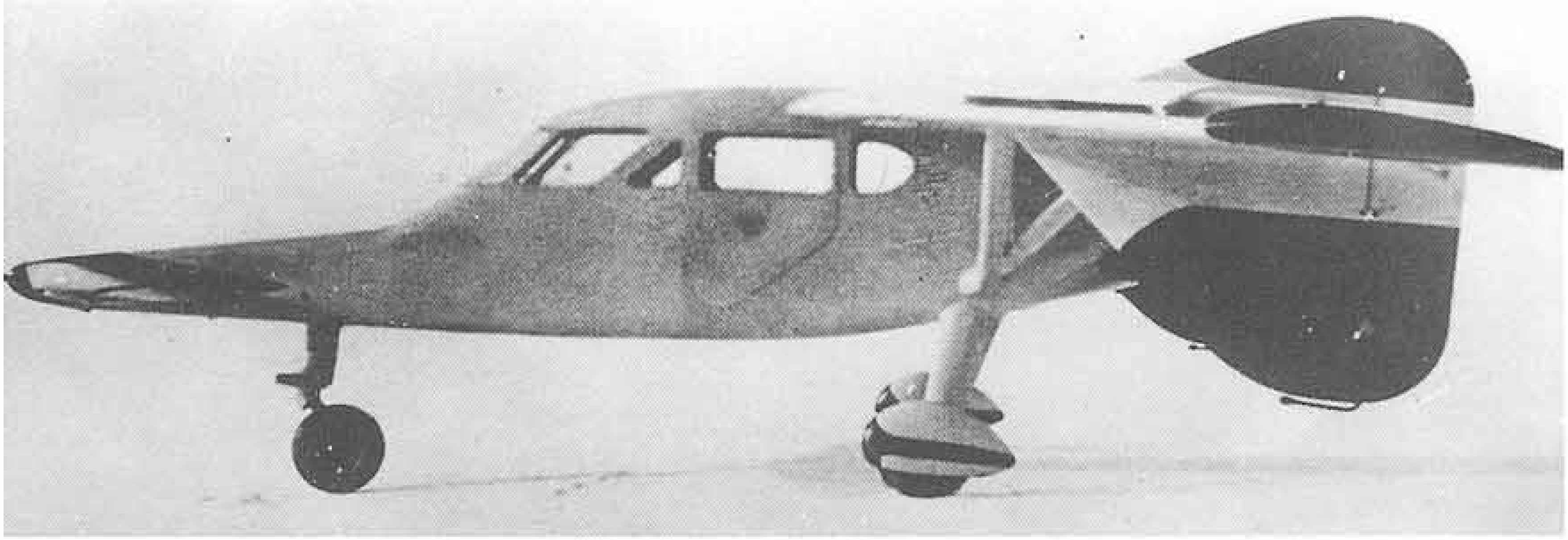
Marking a total break with the OKB's normal work, this light aircraft was built to investigate the handling of an aircraft with what was then a radical configuration, combining a canard elevator, a swept wing and a pusher propeller. It was spurred by the sudden emergence of jet propulsion and German research on swept wings. Called *Utka* (duck) from its canard layout, it was especially intended to discover how a swept wing that was not in the slipstream from a propeller would behave at low speeds.

Most of the design task was assigned to students at the VVA academy under Prof G A Tokayev. It was a simple machine, with a wooden structure covered in fabric. The profile of the untapered wing was Clark YH, with a thickness/chord ratio of 12 per cent, sweepback of 20° and anhedral of –2°. The fuselage housed the pilot on the centreline and two passengers or test observers behind. On the extended nose was the fixed foreplane with tabbed elevators. On the wing were Scheibe fin/rudder surfaces, inclined inwards and tested first on the wingtips and later at 55 per cent span (4.84m apart). Various arrangements of slats, flaps and ailerons were investigated.

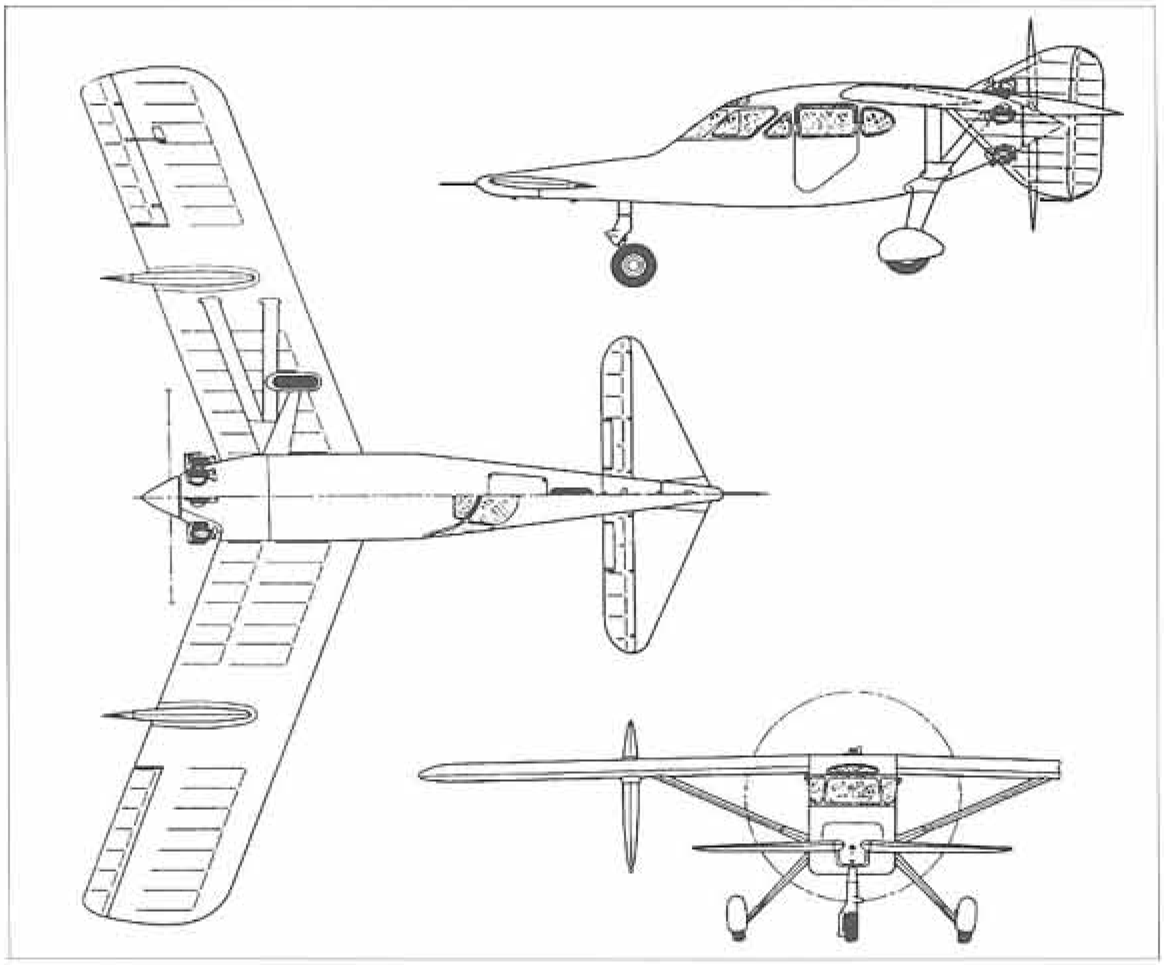
The engine was an M-11FM five-cylinder air-cooled radial derated to 110hp, initially fully cowled with helmets over the cylinders which were later removed. It drove a 2.36m



MiG-8 Utka *as built.*



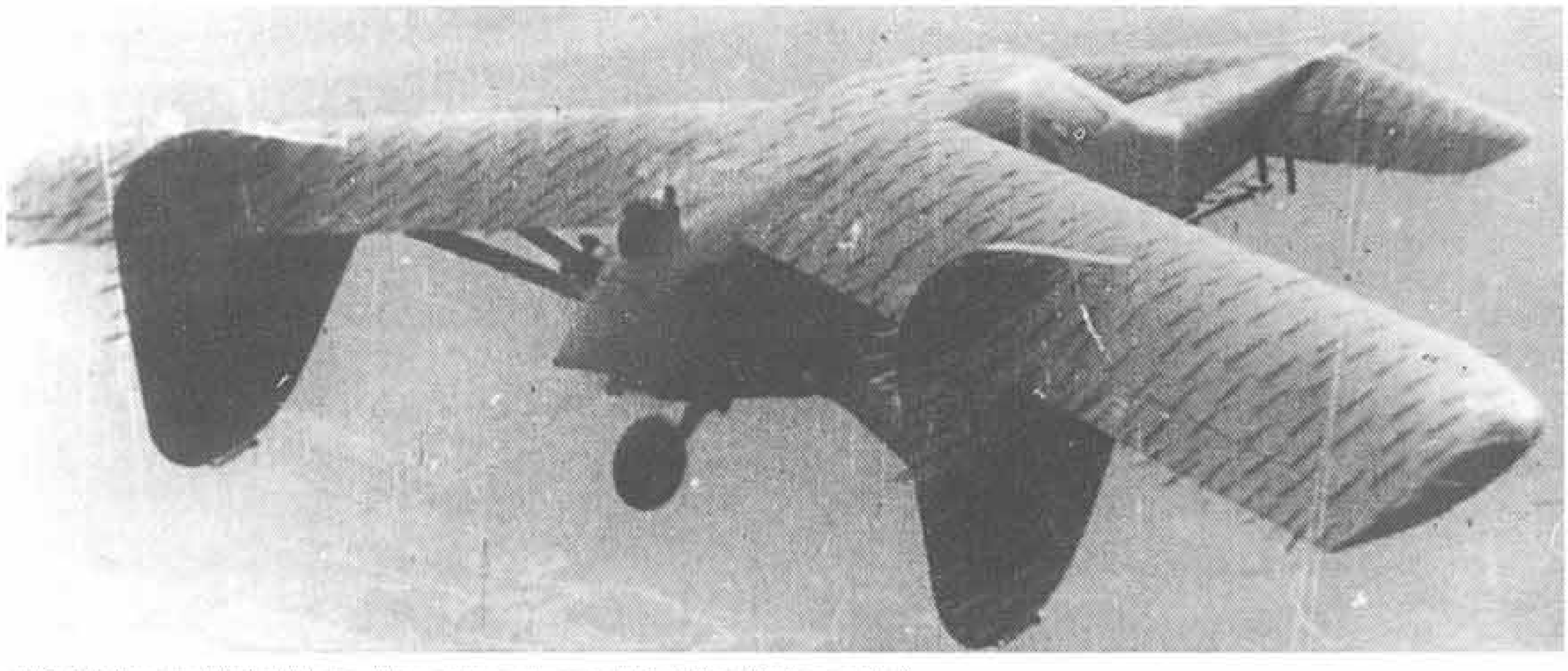
MiG-8 Utka *modified*. (Yefim Gordon archive)



MiG-8 Utka *(final form)*.

(92.9in) two-blade fixed-pitch wooden propeller. A total of 195 litres (42.9gal) of fuel was housed in two aluminium tanks in the inner wings. The 18lit (4gal) oil tank can be seen in the section drawing attached behind the rear cabin bulkhead. The non-retractable tricycle landing gear had a nosewheel with a 300 × 150mm tyre lever-suspended from an oleo leg, and braked mainwheels with 500 × 150mm tyres on pneumatic shock struts. Track was 2.5m (98.4in) and wheelbase 2.996m (9ft 10in).

Programme chief engineer was E F Nashchokin. The first flight was made on 19 November 1945 by A I Grinchik. From the outset this odd machine was a success, though it was tinkered with for months, the wings being tufted and almost every aerodynamic surface being repeatedly altered. As well as Grinchik, test pilots included A I Zhukov and A N Chernoburov. Stability was outstanding,



MiG-8 Utka *as modified with inboard fins, with aerodynamic tufts*. (Yefim Gordon archive) and spinning proved impossible. By 1947 the spats had been removed and the nosewheel fitted with a tyre of the same size as the main units, and the *Utka* then served for many years as the OKB liaison aircraft.

Span 9.5m (31ft 2in); length 6.995m (22ft 11⅜in); wing area 15sq m (161.5sq ft).

Weight empty 642kg (1,415lb); fuel 140kg (308.6lb); oil 14kg (31lb); weight loaded 1,150kg (2,535lb).

Maximum speed 205km/h (127mph); range 500km (311 miles); landing speed 77km/h (48mph). No other data.

I-260, F project

In February 1945 the principal Soviet fighter designers were summoned to the Kremlin. Stalin was angry at the absence of any programme to produce turbojet aircraft. They were instructed to build some as quickly as possible, using captured German engines or Soviet copies. The timing is strange, because the existence of German jets had been known long before, and the fact that Britain and the United States had jet aircraft had been announced in January 1944.

Yakovlev and Lavochkin were told to use a single engine and fit an armament of two 23mm guns. Mikoyan and Sukhoi were told to use two engines and fit a 57mm gun. First flights were expected in about six months.

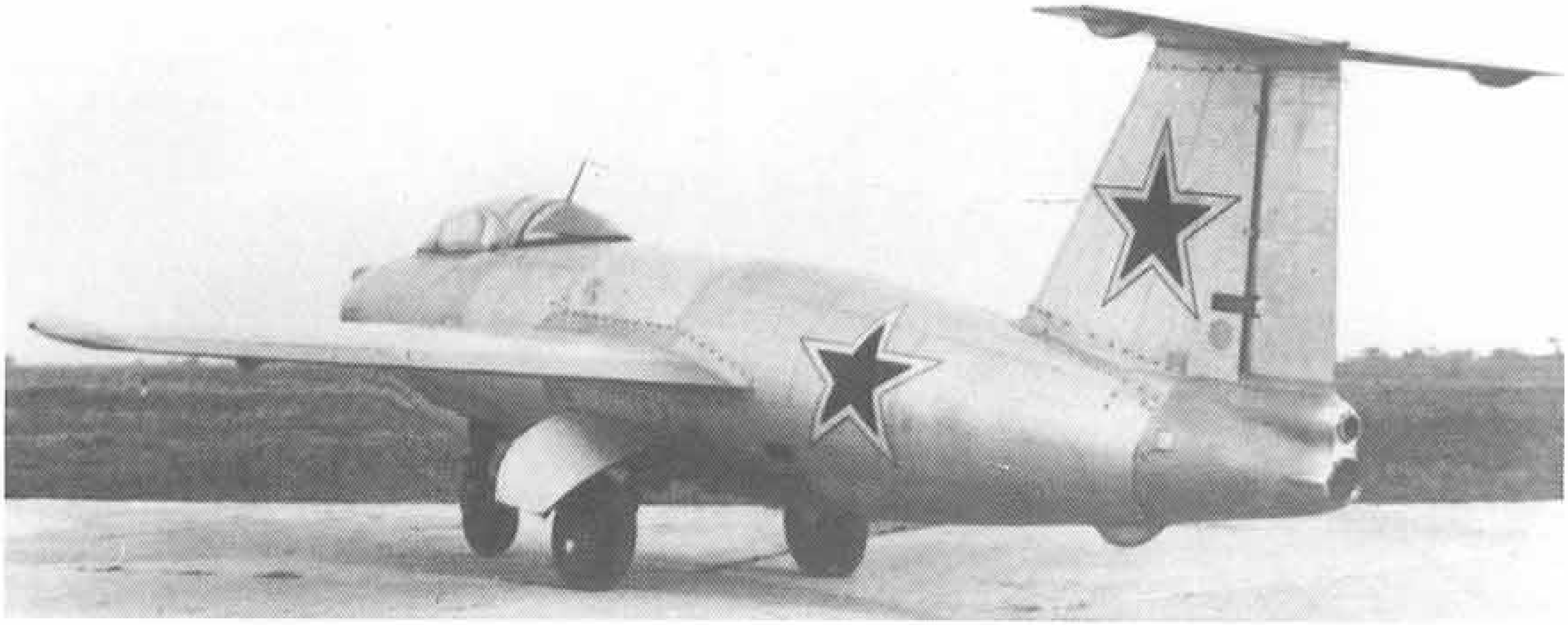
The majority of engineers in the NKAP and GUAP were of the opinion that, before attempting indigenous designs, a minimum-risk programme should be completed to copy the Me 262. Accordingly, the OKB's initial twin-jet project, called *Izdeliye* F, and with Service designation I-260, had engines hung under the wings. Work proceeded rapidly for some weeks until Mikoyan decided that the German aircraft did not have to be slavishly copied, and that there were advantages in putting the engines in the fuselage, in a way impossible with piston engines. Accordingly, he requested and received permission to start afresh with the I-300. Sukhoi carried on with his copy, which led to the Su-9.

I-270, Zh

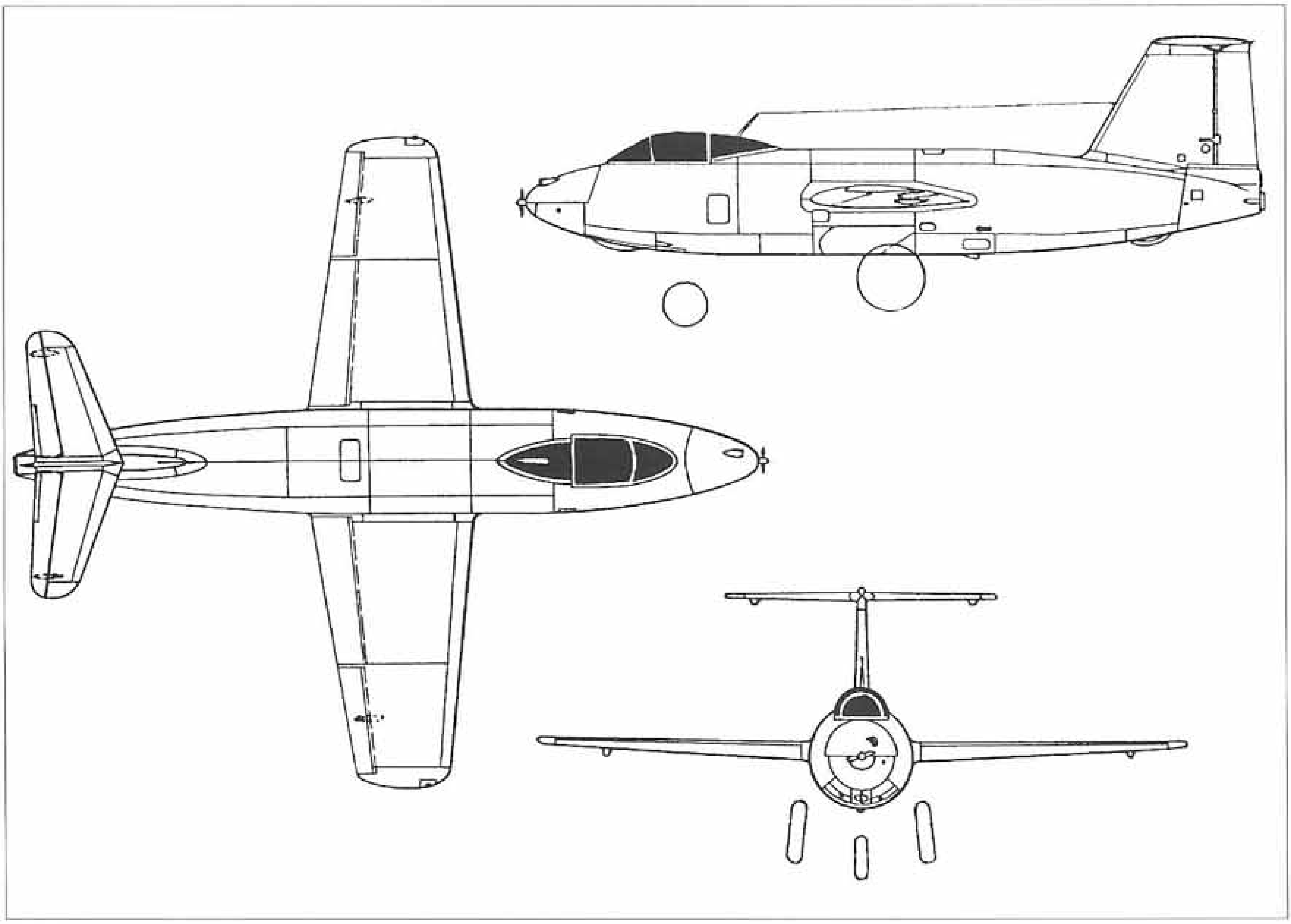
The Soviet Union had been a major pioneer of rocket-engined aircraft, using liquid-propellant engines developed by the KBs of Tsander, Korolyov and, later, that of L S Dushkin and V P Glushko. Important rocket types included the BI-1 and Polikarpov's *Malyutka*. Emergence of the Me 163B rocket interceptor in 1944 prompted the MiG OKB to sketch similar aircraft, but nothing was ordered until after the war, when full information on the Ju 248 (Me 263), including an actual example, became available. The OKB was then given a contract for two prototypes of an aircraft in this class. So was Moskalyev, with the SAM-29, or RM-1.

Aircraft Zh, which received the GUAP designation I-270, was as far as possible a low-risk project. The engine was the Dushkin/Glushko RD-2M-3V, with two pump-fed chambers burning RFNA (red fuming nitric acid) and kerosene, ignited spontaneously by injecting 80 per cent hydrogen peroxide. Thrust at sea level of the main chamber was 1,450kg (3,197lb), and that of the small upper chamber was 400kg (882lb); thrust at high altitude would have been 15–20 per cent higher in

I-270 takeoff. (Yefim Gordon archive)



I-270. (OKB, RART/GP)



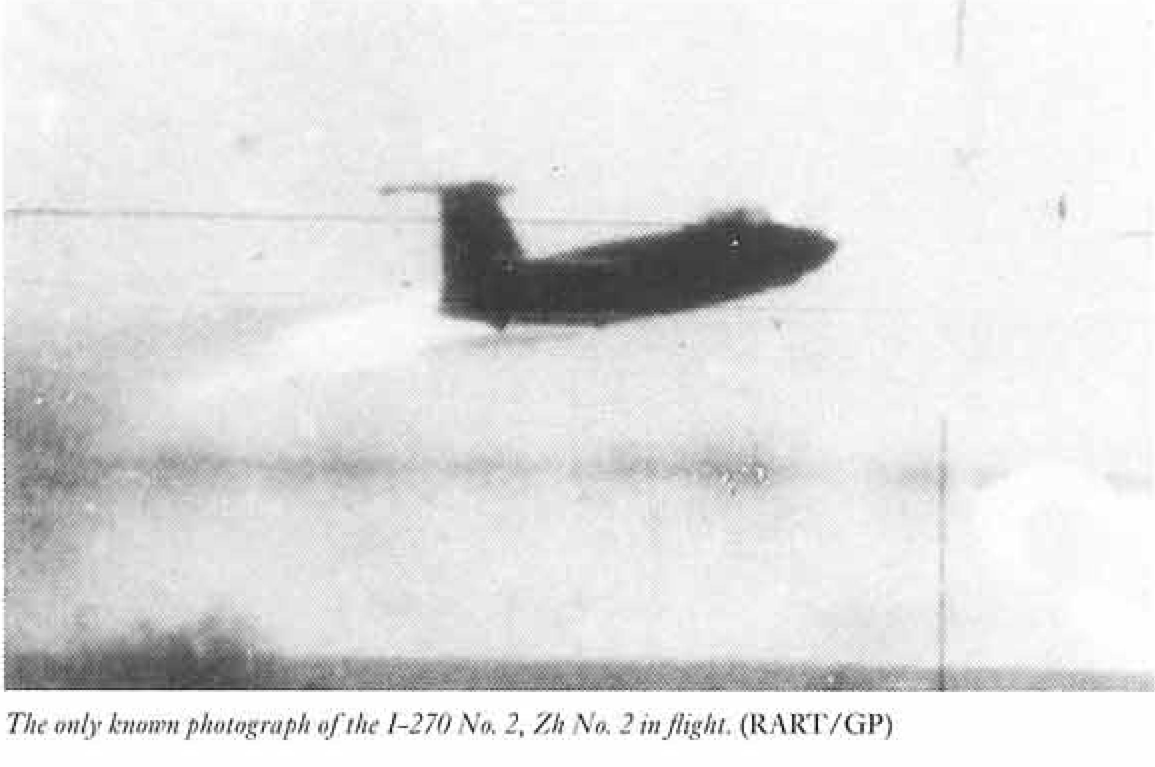
I-270.

each case. Takeoff and high-speed dash was to be made with both chambers in action, when endurance was 4.5 minutes. In cruising flight, with the main chamber inoperative, endurance was 9 minutes.

The airframe could hardly have been simpler. Structure was duralumin stressed skin, the only unusual features being that the one-piece wing had five spars and that, to position the horizontal tail clear of any possible wake from the wing, it was mounted on top of the fin (distance above the wing was 1.2 times mean aerodynamic chord. The tailplane was fixed, and had slight sweepback, though no attempt was made to sweep the wing. The latter had a fixed leading edge and slotted flaps inboard of conventional ailerons. The tabbed elevators and one-piece rudder were also quite normal, though the elevators, like the ailerons, had rather clumsy mass balances.

The circular-section fuselage was similar to that of the Ju 248 but rather more capacious, and it was made in two parts with a bolted connection behind the wing's rearmost spar. For the first time the designers could put the cockpit in the nose, giving the pilot an outstanding view. The cockpit was pressurized from air bottles, and the seat was fitted with an ejection gun energized by cordite. The tricycle landing gear had a very narrow track (1.6m, 63in) despite the mainwheels being inclined outwards, the wheelbase being 2.415m (7ft 11in). Brakes and retraction were from the air bottles.

Behind the seat almost the entire fuselage was occupied by four tanks housing 1,620kg (3,571lb) of acid, one housing 440kg (970lb) of kerosene and seven stainless bottles housing 60kg (132lb) of peroxide. Feed was by turbopumps, with a starting pump driven electrically. The batteries were



The only known photograph of the I-270 No. 2, Zh No. 2 in flight. (RART/GP) recharged by an Me 163B windmill generator on the nose. Armament comprised two NS-23, with 40 rounds each. A plan to fit underwing racks, for example for four RS-82 rocket pods, was not agreed.

Several OKB and NII-VVS pilots trained to test the I-270 by flying a Yak-9 loaded beyond normal maximum weight with lead bars. This gave a useful approximation to the rocket interceptor's handling qualities.

The Zh No. 01 was completed before the rocket engine had been cleared for flight. It was thus finished off as a glider, with no rocket and no windmill generator or armament, although it did have radio. This made an enormous difference to the loaded weight, and early tests merely confirmed acceptable handling over speeds up to 300km/h (186mph). The assigned pilot was V N Yuganov, who from early December 1946 made successful gliding flights after a tow behind a Tu-2.

These tests were not very useful, and the real test programme began about three weeks later with the release to flight test of the Zh No. 02. This was a more refined aircraft, with an unpainted but polished exterior with red/white-bordered national insignia. It had the rocket engine, nose windmill and guns, and was in all respects representative of the proposed I-270. It began flight testing under power in early January 1947, and initially gave good results.

Unfortunately, neither aircraft had a long life. In early 1947 a VVS pilot, A K Pakhomov, made a clumsy landing in Zh No. 02 which caused damage beyond economic repair. A few weeks later Yuganov belly landed Zh No. 01, and nobody bothered to repair it. It was obvious that such aircraft were not very useful.

Span 7.75m (25ft 5in); length 8.915m (29ft 3in); wing area 12sq m (129sq ft).

Weight empty (No. 02) 1,546kg (3,408lb); propellants 1,620 + 440 + 60kg (4,674lb); weight loaded 4,120kg (9,083lb).

Maximum speed 1,000km/h (621mph) at sea level, 900km/h (559mph) at 5,000m (16,404ft), 928km/h (577mph) at 10,000m (32,808ft), 936km/h (582mph) at 15,000m (49,200ft); climb to 10,000m (32,808ft) 2.37min; service ceiling 17,000m (55,775ft); takeoff run 895m (2,936ft); landing speed (propellants exhausted) 137km/h (85mph); landing run 493m (1,617ft).

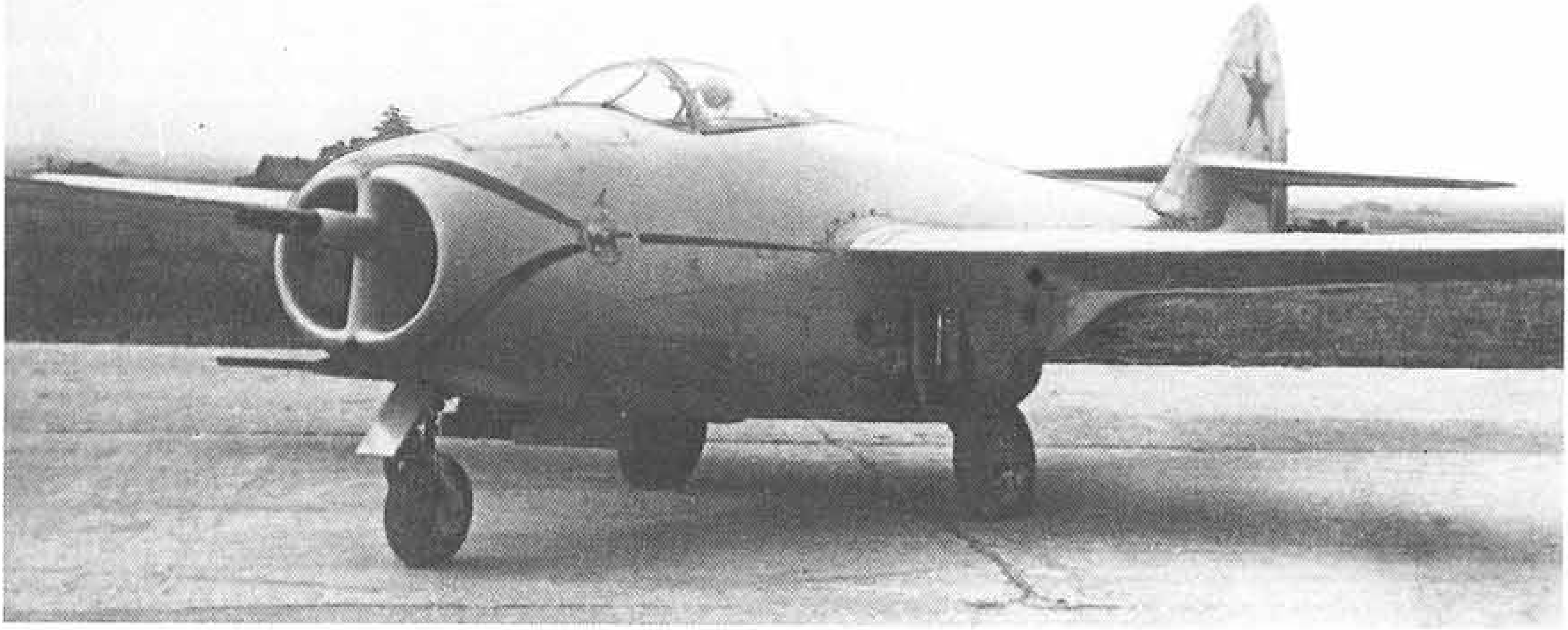
I-300, F

Following the summons to the Kremlin in February 1945, Mikoyan had immediately gathered a team and set them the task of producing a copy of the Messerschmitt Me 262. On 9 April 1945 OKB-155 was given a formal government directive to build a jet fighter. The demand specified the use of two BMW 003A engines. Numerical requirements comprised a speed of 900km/h (559mph) at sea level and 910km/h (565mph) at 5,000m (16,404ft), a range of 820km (509 miles), a time of 4 minutes to reach 5,000m and armament of one or two guns of 57mm or 37mm calibre plus two of 23mm. Three prototypes were ordered, the first to be delivered for testing on 15 March 1946.

As noted earlier (I-260) Mikoyan recognized that there were advantages in drag, combat manoeuvrability and engine-out handling in a more compact arrangement with the engines in the fuselage, with jet nozzles about midway between the nose and tail. A T Karyev had previously studied such a layout in a fighter to be powered by a single Lyul'ka TR-1 engine, and for Aircraft F it was merely necessary to modify the engine bay to match the slimmer low-powered BMW engines arranged side by side. Mikoyan considered that this did not pose unacceptable risk.

Karyev as chief engineer was joined by A G Brunov as chief project engineer. By this time the war was over, and the OKB was given until 1 September 1946 to submit the first prototype for NII-VVS evaluation. This schedule was improved upon. According to A V Minayev, this was because of 'the large amount of R & D conducted during the war'.

Apart from the novel method of propulsion, and the tricycle landing gear – the first on a Soviet fighter, because the BB-MAI, *Malyutka*, Belyayev EOI (PBI) and Gu-1 had never been completed – Aircraft F was a conventional low-risk design, entirely of D16 light alloy. The two-spar wing



I-300. (OKB)

had most of its taper on the trailing edge. The aerofoil profile was CAHI-1-A-10 near the root, changing to 1-B-10 near the tip, with a ruling thickness/chord ratio of 9 per cent. The wing was set at an incidence of +1°, and anhedral angle was –2.5°. The leading edge was fixed, and on the trailing edge were large one-piece slotted flaps and Frise ailerons.

The fuselage was designed in front and rear sections, bolted together at Frames 15/15A. The two inlet ducts bifurcated from the extreme nose and led down to the closely spaced engines, which were hung under the wing spars and were easily accessible through large cowl panels. Immediately downstream of the jet nozzles, from Frames 19 to 34, the underskin of the rear fuselage comprised curved panels of stainless-steel sandwich 15mm (0.59in) thick, with a corrugated core through which cooling air could flow. The engine bays were fireproof, and ventilated and cooled by air rammed in from two inlets in tandem on each side of the fuselage under the wing.

The tail was attached to Frames 32, 34 and 35. Both the vertical and horizontal surfaces had a profile of NACA-0009. To avoid interference from the jets the tailplane was fixed to the fin well above the level of the fuselage. On the ground it could be set at any incidence from 1° 10′ (which was standard) to –4°. All the control surfaces were made entirely of duralumin, the skin being 0.3 or 0.5mm. The ailerons and elevators were driven by rods, levers and bellcranks, and the rudder by cables.

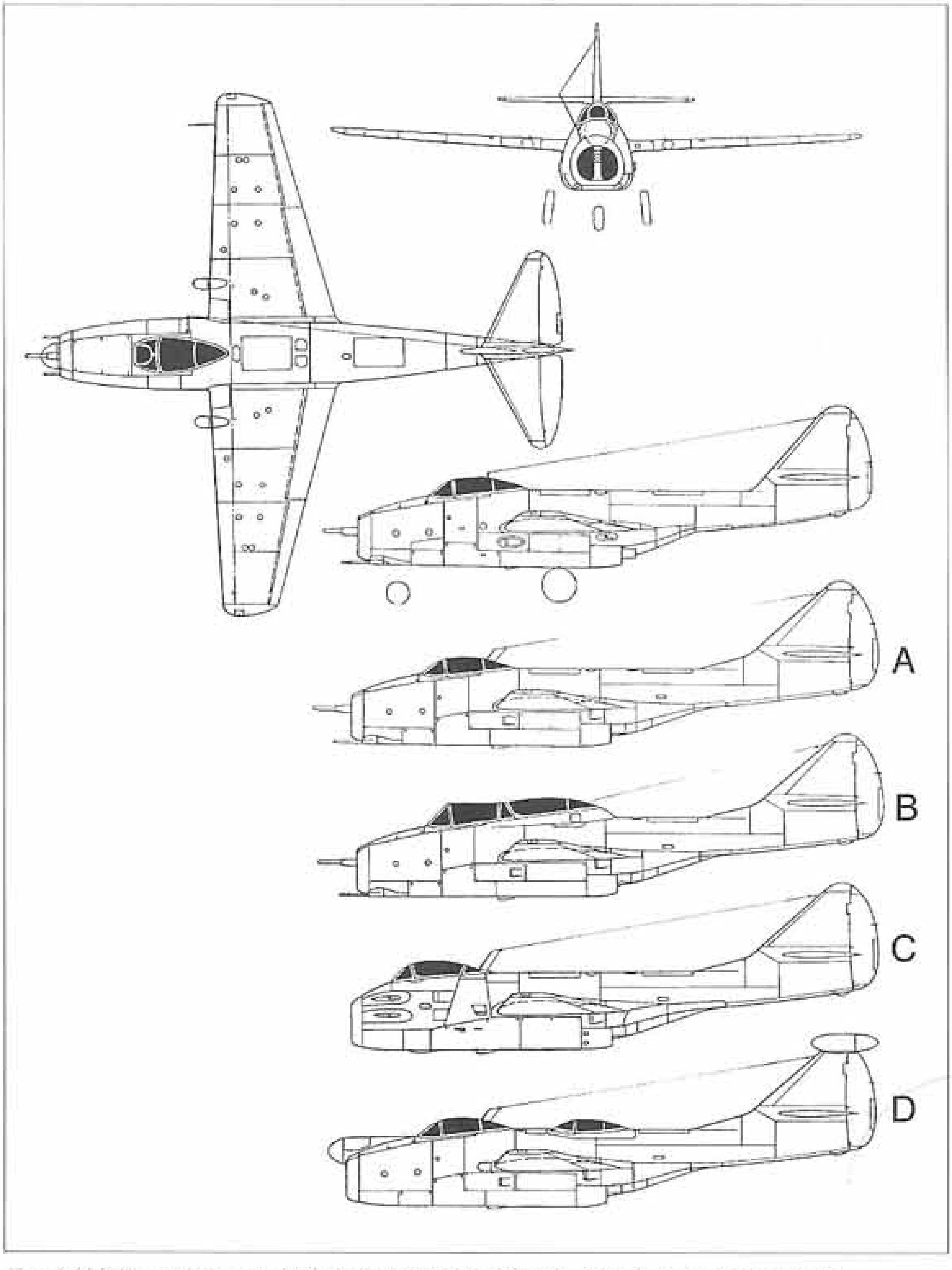
The neat landing-gear units all had single legs carrying levered-suspension trailing links. The castoring nose unit was fitted with a shimmy damper, and retracted backwards into a bay between the engine ducts sealed by three doors. The tyre size was 480 × 200mm. The main units were pivoted to trunnions behind the main spar at the wing root. They retracted outwards into an interspar compartment sealed by a door on the leg and another, outboard of the bay, hinged to the wing. Tyre size was 660 × 160mm. Track was 1.95m (76.8in) and wheelbase 3.072m (120.94in).

Actuation of the landing gear and flaps was hydraulic. Each engine drove a hydraulic pump, serving a simple closed circuit. The left engine also drove a GSK-1500 d.c. generator, charging a 12A-10 battery. A total of 1,635 litres (359.7gal) of fuel was housed in four fuselage tanks and three in each wing, all of protected rubberized fabric. Until aviation jet fuels became available in 1947 the fuel was T-2, the kerosene used by agricultural machinery. Each engine was started by a German Riedel two-stroke piston engine served by a small tank of petrol.

The cockpit, which was unpressurized, extended between Frames 5 and 11A. The windscreen was a bulletproof laminate with a thickness of 55mm (2.17in). The canopy was a single 'teardrop', sliding to the rear on tracks. A standard nonejecting seat was fitted. Comprehensive armour was provided, the rear panel having a thickness of 12mm. The KP-14 oxygen system was certified to an altitude of 12,000m (39,370ft). The radio was the RSI-6M, with a wire antenna from the cockpit to the top of the fin. Other equipment included an RPKO-10M radio compass, PKI-1 gunsight and an S-13 combat camera in the port wing root.

To obtain a good centre-of-gravity position the armament was mounted as far forwards as possible. It comprised an enormous OKB-16-57 gun in the division between the inlet ducts, with a 28-round magazine, and two NS-23 guns, each with 80 rounds, in the bottom of the fuselage. All empty cases were collected between Frames 1–6. There was no requirement to fit racks under the wings.

With the war over it was considered prudent to conduct a review of a mock-up, and this was finished in December 1945 and approved in January 1946. By this time assembly was well advanced on Aircraft F No. 1, or I-300, the first of the three proto-



Top: I-300 (three views); A: MiG-9; B: UTI MiG-9/F; C: MiG-9M; D: MiG-9L/FK.

types. This was rolled out of the prototype workshop on 6 March 1946. It was painted a pale colour all over, with a contrasting coloured trim which for the first time included the OKB's logo at the start of a cheat line on each side. The pilot assigned to the aircraft was Aleksei Nikolayevich 'Lyosha' Grinchik, who after distinguished war service had been appointed deputy flight-test director at the LII. The supporting team comprised Karyev and mechanics V V Pimyenov and G Bushtinov.

Taxi testing began on 12 April, leading to a short hop three days later. At 11.12am on 24 April 1946, following the toss of a coin, Grinchik took off on the first jet flight in the USSR (M I Ivanov flew the Yak-15 two hours later). Grinchik's flight lasted six minutes. On the eighth flight severe buffet was suddenly encountered around or behind the engines. Three further cautious flights failed to identify the cause. Some experts were still afraid of the radical location of engines in the fuselage, and mathematician M V Keldysh recommended relocating them 'under or over the wings', but when the steel-sandwich heatshields downstream of the jet nozzles were reinforced the buffet disappeared.

On Flight 19, on 11 July, during a spirited low-level demonstration for VIPs, one wing/fuselage fairing broke off. It severely damaged the tailplane, causing the aircraft to crash. Grinchik was killed. By this time the other two prototypes were almost complete. F-3 was first flown by LII pilot Mark Lazarevich Gallai on 9 August 1946, and F-2 by G M Shiyanov two days later. On 18 August Shiyanov led the Air Force Day parade over Tushino. Gallai made the first firing trials, and gases from the N-57 caused such trouble with the engines that the enormous gun was replaced by an N-37, with 40 rounds.

Both prototypes were delivered to NII-VVS on 26 October, testing starting two days later. Under Chief Engineer A Rozanov, the new twin-jets were evaluated by A G Proshakov, P M Stefanovskiy, D G Pikulenko, Yu A Antipov, A M Khripkov, G A Sedov and A G Kubyshkin. They carried out all combat manoeuvres, including spinning, and encountered many problems. One was that firing the three guns at heights over 7,000m (22,965ft) was likely to cause engine flameout, unless indicated airspeed (IAS) exceeded 320km/h (198mph). As before, it was the big central gun that caused most trouble; with just two NS-23K side guns there was no problem with IAS over 320km/h up to a height of 10,700m (35,100ft).

Overall the I-300 was considered an easy aircraft to fly, and devoid of any serious shortcomings in flying qualities. On the other hand, the prototypes suffered from a seemingly endless succession of problems. One was the basic immaturity of the engine, which was at first given a time between overhauls (TBO) of 25 hours. Both F-2 and F-3 had quite short lives, one having an accident in the hands of Antipov, while the other was landed wheels-up in a field by Pikulenko.

Nevertheless, the I-300 was clearly the best of the first generation of Soviet jet fighters, and it was ordered for VVS service as the MiG-9. The engines were to be a Soviet copy of the BMW 003A, designated RD-20.

Span 10m (32ft 9¾in); length (excluding guns) 9.75m (31ft 11⅞in); wing area 18.2sq m (195.9sq ft).

The following are OKB figures:

Weight empty 3,283kg (7,283lb); fuel 1,334kg (2,941lb); oil 35kg (77lb); petrol 7kg (15.4lb); weight loaded 4,860kg (10,714lb).

Maximum speed 864km/h (537mph) at sea level, 920km/h (572mph) at 4,500m (14,764ft); climb to 5,000m (16,404ft) 4.5min, to 10,000m (32,808ft) 14.3min; service ceiling 13,000m (42,650ft); range 810km (503 miles); takeoff run 910m (2,990ft); landing speed 170km/h (106mph); landing run 735m (2,911ft).

The following are NII-VVS figures, from aircraft 110426, which had below-average engines:

Weight loaded 4,988kg (10,996lb).

Maximum speed at sea level as above, 910km/h (565mph) at 4,500m (14,764ft), climb to 5,000m (16,404ft) 5.35min; service ceiling 11,700m (38,386ft); range 800km (497 miles); takeoff run 920m (3,018ft); landing speed 180km/h (112mph); landing run 950m (3,117ft).

I-301, FS, MiG-9

In August 1946, when only the F-1 prototype had flown, Factory No. 1 at Kuibyshev was instructed to prepare for production of the I-300, in advance of an order. *Izdeliye* FS signified Aircraft F, Series. Perhaps predictably, the factory was also told to proceed with a preliminary series of ten aircraft, to be made in an emergency programme in order to participate in the 7 November Tushino air parade commemorating the October Revolution.

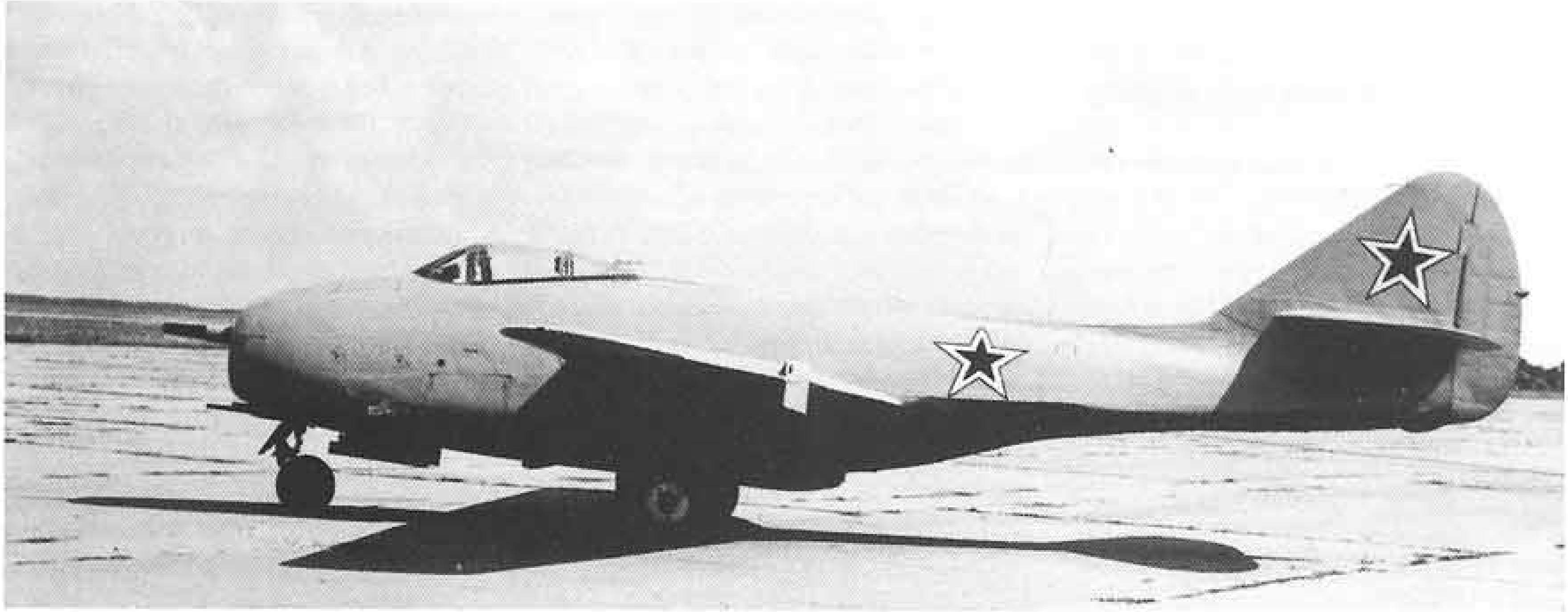
This demand was made on 28 August, and in order to meet it the aircraft had to be constructed in advance of delivery of the production tooling. Accordingly, the demand was met with ten hand-built prototypes, powered by refurbished BMW 003A engines. This frantic effort unquestionably delayed the main programme.

The eventual production MiG-9 suffered from numerous problems, and when, years later, VVS C-in-C Marshal K A Vershinin exclaimed 'There is not one MiG-9 without problems' the OKB-155 reply was 'We had no time to carry out proper development, we were rushed into readying aircraft for parades'.

By working three shifts the factory completed all ten hand-built aircraft between 13 and 22 October 1946. They were taken by train to the LII, where they were flown by all the previously mentioned NII-VVS and LII pilots. Then, as had so often happened, bad weather on 7 November resulted in the flypast being cancelled.

In the course of 1946 D V Kolosov formed a special group, not a proper KB, at the Kazan engine factory (No. 17) to produce drawings and tooling for the RD-20, a Soviet version of the BMW 003A (*see* Appendix 1). Production engines became available from late 1947. Like the original German turbojet they were rated at 800kg (1,764lb) takeoff thrust. They were initially lifed at 25 hours, but later the TBO was extended to 75 hours. They powered all the series MiG-9 fighters, the first of which was completed in autumn 1947 and delivered to the VVS in January 1948. It was accepted on 1 May 1948.

Here again the programme was seriously disrupted, initially by NKAP Directive 2698–1114 of 16 December 1946 that Factory No. 1 should build forty-eight aircraft to take part in the air parade of 1 May 1947. This was followed by Directive 1626–434 of 20 May 1947 that the factory should initially build one hundred aircraft without the N-37 gun, which was to be introduced (after correcting the previously mentioned difficulties) in the third and fourth quarters of 1947. In fact, the N-37 was never authorized for the production MiG-9. OKB records show that by 2 February 1948



First production MiG-9, with airbrakes open. (OKB, RART/GP)

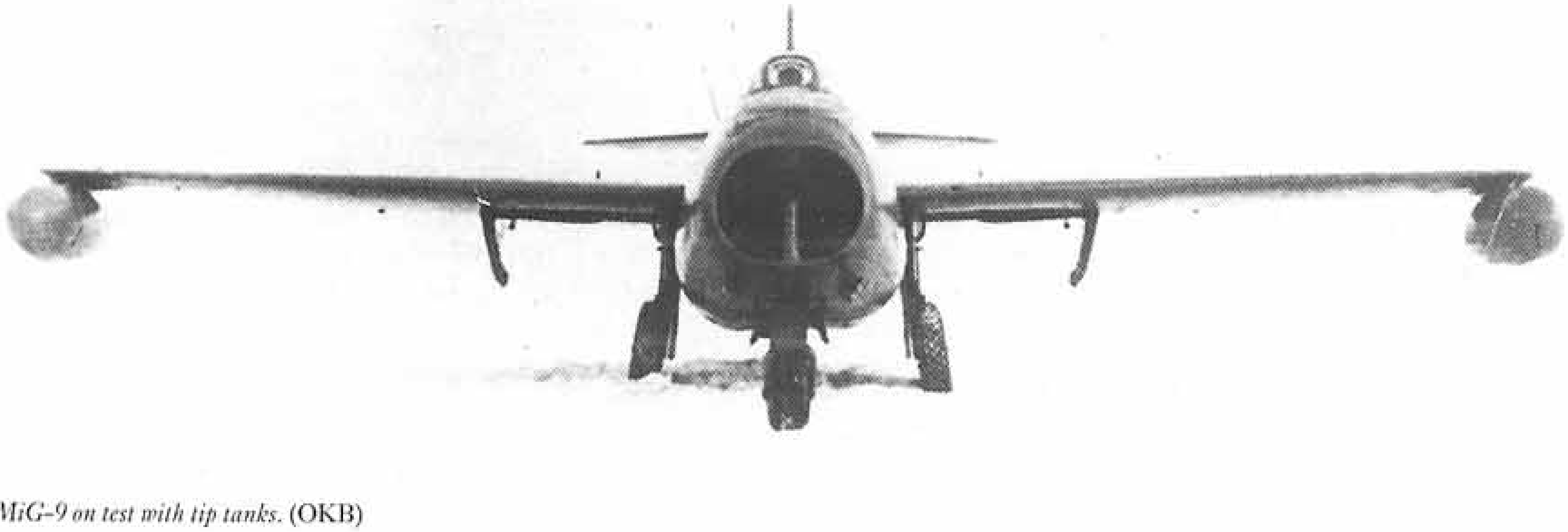
the VVS had received ninety-seven series aircraft armed with three NS-23K guns, each with 80 rounds.

Initially the series MiG-9 differed visibly from the thirteen development aircraft only in having a fin of considerably increased chord, plus a small dorsal fin. This greatly improved directional stability. Other important changes were to increase the capacity of the brakes on the mainwheels and to install fuel tanks made of a new rubberized-fabric developed in 1945 at the VIAM (All-Union Institute for Aviation Materials). The tanks offered greater protection but, contrary to what is implied in some books, capacity was slightly reduced.

One engine drove a hydraulic pump and the other a GSK-1500 generator charging a 12A-10 battery. Equipment included an RSI-6 shortwave (vhf) radio, RU-45A radio static converter, US-1000 airspeed indicator (a Machmeter was being developed for retrofit), VD-12 altimeter, electric horizon, *Khorn* direction indicator, PDK-44 compass, VR-30 vertical speed indicator, TF-15 tachometers, MR-80 fuel pressure, EDMU-1 jetpipe pressure, TVG-44 thermometer, TME-45 oil temperature and BE-296 fuel contents instruments.

The final production batch incorporated several improvements, which were retroactively fitted to most of the preceding aircraft. The most important modifications were to add cockpit pressurization and an ejection seat (*see* UTI MiG-9). Another addition, for which pilots had clamoured, was to incorporate a simple rectangular airbrake into the outer part of each wing flap, pivoted near the centre to reduce the hinge moment. When opened at 90° these greatly increased deceleration, though they could not reduce the landing speed. Numerous other modifications were introduced, among them reinforced landing-gear doors which had sometimes been torn off or distorted on takeoff or landing. Many other shortcomings were blamed on bad workmanship at Kuibyshev. One aircraft was fitted with jettisonable fuel tanks under the wingtips, each with a capacity of 235 litres (51.7gal). Several others were used for armament experiments.

Though some OKB records suggest that only 250 series aircraft were built, the actual figure appears to have been 500. This tallies well with the OKB's published production total of 604 MiG-9 aircraft of all types, including prototypes. The MiG-9 officially entered service in the VVS on 1 July 1948. The first *divisia*, comprising three regiments, was commanded by Col G Lobov and formed part of the 1st Air Army based at Kobrin. At first, because in the VVS Yakovlev had a far higher reputation than MiG, pilots preferred the small and agile Yak-15, based on the piston-



MiG-9 on test with tip tanks. (OKB)

engined Yak-3. Gradually it became known that the overall handling of the MiG-9 was superior, and the twin-engined aircraft also had a higher performance. Thus, for the first time, the MiG OKB gained a position of pre-eminence, which it has never lost.

Even after the public flypast on 18 August 1946, nothing about the MiG-9 appeared in Western publications. At last, very poor photographs and artist's drawings of the MiG-9 appeared in *The Aeroplane Spotter* for 17 May 1947, where it was described as a Lavochkin design with 'three pitot tubes' in the nose. The MiG-9 received the USAF designation 'Type 1', later replaced by the ASCC reporting name 'Fargo'.

Dimensions unchanged except length (ignoring guns) 9.83m (32ft 3in).

Weight empty 3,420kg (7,540lb); fuel 1,298kg (2,861.6lb); oil/petrol unchanged; weight loaded 5,054kg (11,142lb).

Maximum speed 864km/h (unchanged) at sea level, 911km/h (566mph) at 4,500m (14,764ft), climb to 5,000m (16,406ft) 4.3min; service ceiling 13,500m (44,290ft); range 800km (unchanged); takeoff and landing speeds and runs unchanged.

I-301T, FT, UTI MiG-9

The obvious need for a dual-control trainer version of the MiG-9 was recognized by the OKB in May 1946, but with no pressure from the GUAP the FT (T for *trenirovochnyi*) was produced to a leisurely timescale. The mock-up was reviewed and accepted in October 1946, and two prototypes were ordered, designated FT-1 and FT-2. What has yet to be explained is how the deficiencies of FT-1, revealed in August 1947, could all have been corrected by FT-2 which was flown in the same month.

Behind the original cockpit was added a second cockpit for the instructor, with its own sliding canopy. To accommodate it the front fuel cell was removed and the second made smaller, reducing total capacity to 1,040 litres (229gal). FT-1 had full armament, including the N-37, and apart from the additional cockpit was almost standard. Contradicting the statement that Bell P-63 wheels were used, photographs show landing gear with no visible change from the standard.

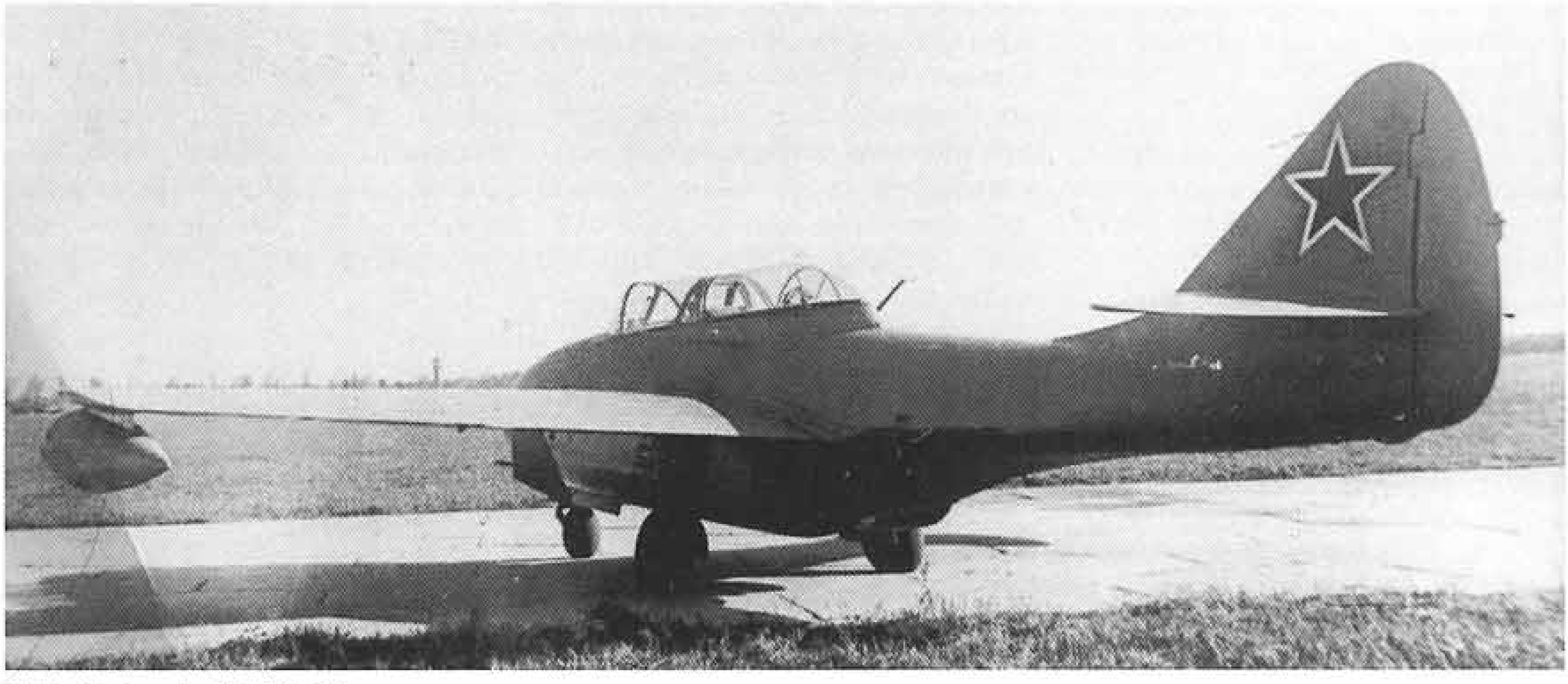
Prototype FT-1 was completed in July 1947 and flown by Gallai on the 8th of that month. A month later it failed NII-VVS certification because the instructor's field of view was considered unacceptable. This aircraft was later used to assist with the development of the first MiG design of ejection seat and other equipment, including the addition of wingtip drop tanks.

The FT-1 may have had German engines but the second prototype, FT-2, had RD-20s, driving the standard Soviet accessories. It differed in numerous respects from its predecessor of three weeks earlier. The rear seat was raised slightly, and the cockpit glazing redesigned with a lower windscreen without a bulletproof slab, a more sharply inclined top line and a bulged cross-section to improve visibility. The Plexiglas partition between the cockpits was omitted. Other changes included the addition of airbrakes and an FKP (combat camera)-type S-13 in the port wing root as in the fighters.

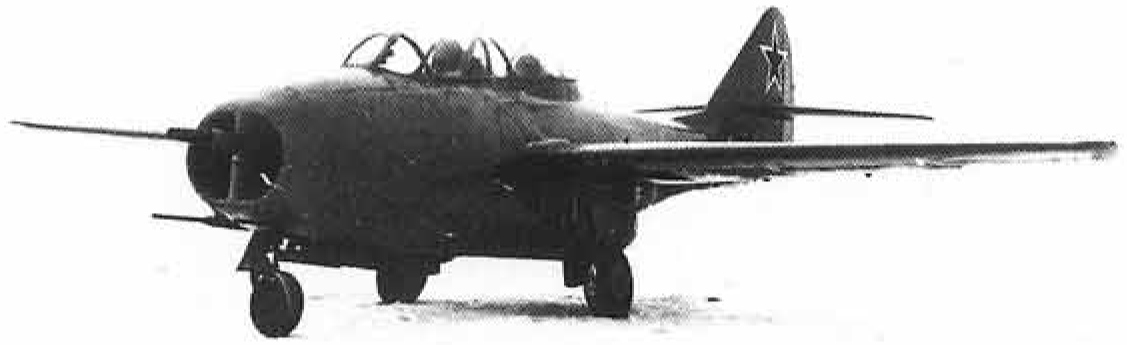
FT-2 was first flown on 25 August 1947. Clearly there were few problems, because on 4 September it was ferried to Moscow Shchelkovo for NII-VSS acceptance trials. Here it was assigned to Maj V G Ivanov, but at the conclusion of these tests on 17 September it had also been flown by eleven other NII-VVS pilots. It passed the evaluation, the report recommending that airbrakes and drop tanks should be standard on all fighter MiG-9s.

The OKB began developing an ejection seat in early 1947, and on 11 March 1947 it received an order to test the seat in the FT-2. After ten test ejections in a static rig the first seat for air testing was installed in the rear cockpit of FT-1, which was with the OKB. It weighed 128.5kg (283lb). Factory testing proceeded successfully throughout the first half of 1948, at speeds up to 700km/h.

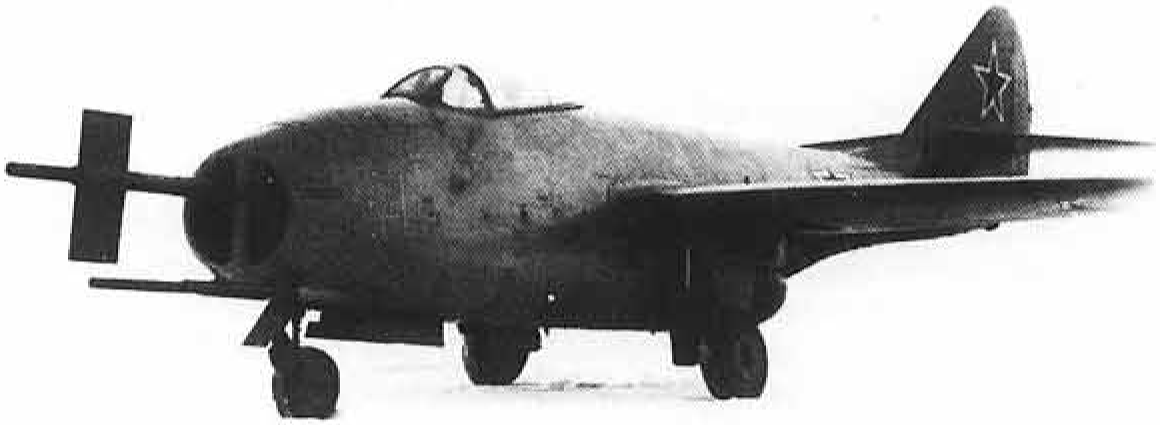
After these tests, the FT-2 was fitted with two ejection seats, installed at 18.5° (rear) and 22.5° (front). The sequence for a genuine escape was: jettison front canopy, jettison rear canopy, fire rear seat, fire front seat. FT-2 was delivered for seat trials at NII-VVS on 29 September 1948. After two tests with dummies, three



FT-1 with tip tanks. (RART/GP)



FT-2. (OKB)



MiG-9 'Babochka'. (OKB)

tests were made by Capt A V Bystrov and N Ya Gladkov at speeds from 517 to 695km/h between 7 October and 13 November 1948.

In 1948 it was planned that 60 dual-control aircraft – at that time called UTI MiG-9 – should be constructed. This is believed to have been the actual total. The type remained unknown in the West, so no ASCC name was allocated.

Dimensions unchanged.

Weight empty (FT-1) 3,584kg (7,901lb), (FT-2) 3,460kg (7,628lb); fuel/oil/petrol (FT-1) 840/35/7kg (1,852/77/15.4lb), (FT-2) 862/22/14kg (1,900/48.5/31lb); weight loaded (1) 4,812kg (10,608lb), (2) 4,895kg (10,791lb).

Maximum speed 900km/h (559mph) at 4,500m (14,764ft); speed at sea level (FT-1) 830km/h (516mph), (FT-2) 810km/h (503mph); climb to 5,000m (16,404ft) (FT-1) 5min, (FT-2) 5.3min [no explanation is available why this lighter version should have climbed more slowly than the fighters]; service ceiling 12,500m (41,010ft); range 530km (329 miles) [this figure, given by V B Shavrov, accords with the OKB figure for endurance of 50min; the OKB claim of 775km appears doubtful]; design range with drop tanks 920km (572 miles); takeoff run 835m (2,740ft); landing speed 190km/h (118mph); landing run 775m (2,543ft).

I-308, FR, MiG-9M

Probably the best-looking and fastest of all the MiG-9 versions actually flown, this aircraft had a redesigned forward fuselage housing the guns well back along the sides, to try to reduce their effect on engine operation. The two NS-23s were mounted much higher up, both on the left side, and the NS-37 was mounted at the same level on the right. This required rearrangement of internal equipment. The cockpit was pressurized.

Another important change was to fit RD-21 engines. Originally designated RD-20F, these were wholly Russian, having been developed from the BMW 003A by D V Kolesov's team at Factory No. 17 at Kazan. The F stood for *forsirovannyi* (intensive), which usually implies afterburning but in this case signified increased combustion temperature. Takeoff thrust was increased to 1,000kg (2,205lb). These engines had Soviet accessories, including electric starters.

Other changes included a reduction in the number of fuel tanks from six to five, including a 100lit trim tank, but total capacity was only fractionally reduced to 1,595 litres (351gal). The flaps incorporated airbrakes. Together with the FT-1 it was the first MiG aircraft fitted with a Machmeter.

The FR, also known as the I-308, was completed in June 1947 and first flown in July by V N Yuganov. It was planned that it should become the future standard fighter, designated MiG-9M, and also lead to single-engined versions (*see* FL, FN). Because of the much greater potential of Aircraft S (which led to the MiG-15), the programme was discontinued.

Dimensions unchanged (ignoring projecting guns of earlier versions).

Weight empty 3,497–3,356kg (7,709–7,399lb); fuel 1,300kg (2,866lb); weight loaded 5,040–5,069kg (11,111–11,175lb), (1996 report) 5,140kg (11,332lb).

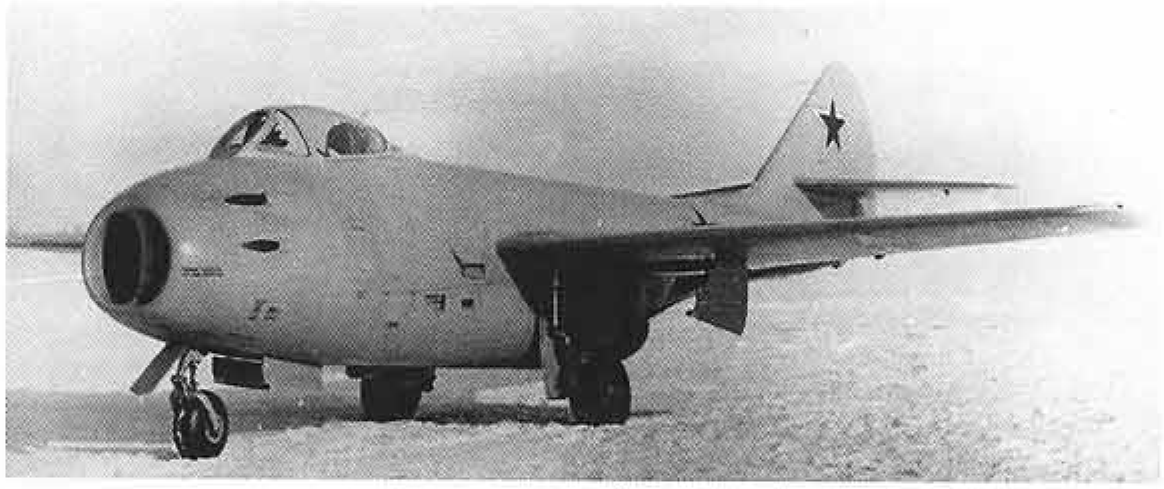
Maximum speed 872km/h (542mph) at sea level, 965km/h (600mph) at 5,000m; climb to 5,000m (16,404ft) 2.7min; service ceiling 13,000m (42,650ft) [1996 report, 14,000m/45,932ft]; range 800–830km (497–516 miles); takeoff run 700–830m (2,300–2,723ft); landing speed 165km/h (102.5mph); landing run 700–740m (2,300–2,428ft).

I-302, FP

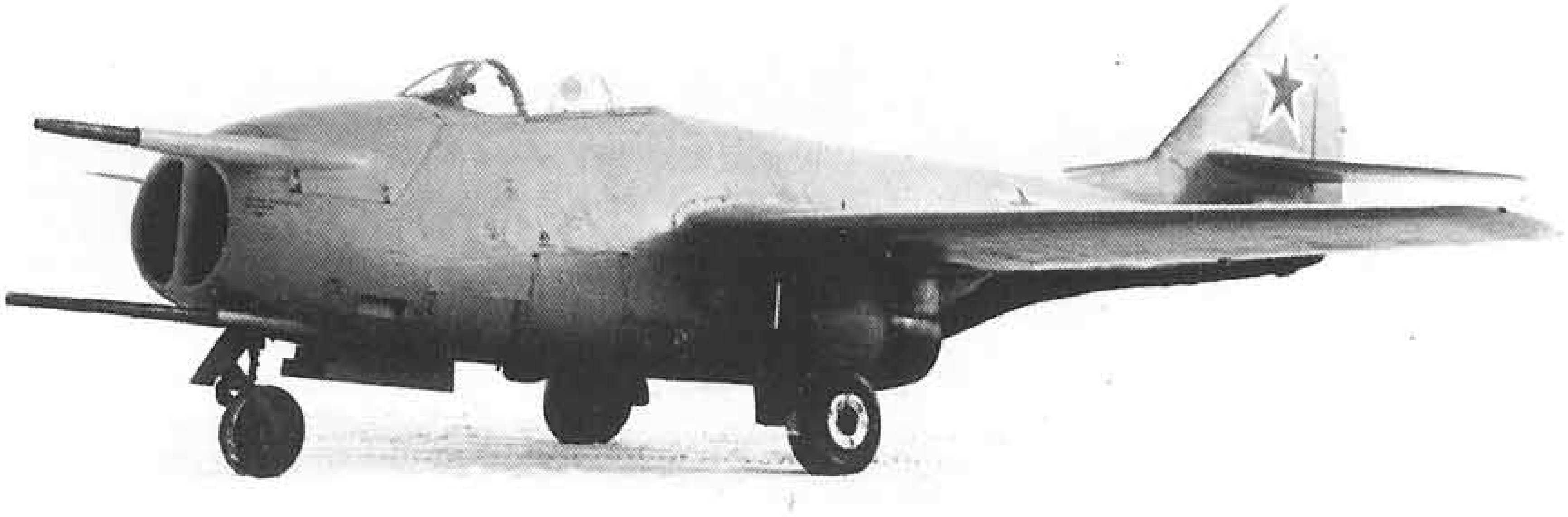
This single aircraft (P for *pushechnyi*, cannon) was a modified series MiG-9 with the N-37 mounted high on the left side of the nose, well outside the engine inlets. It did little to help the problem of engine stall on firing this gun.

I-307, FF

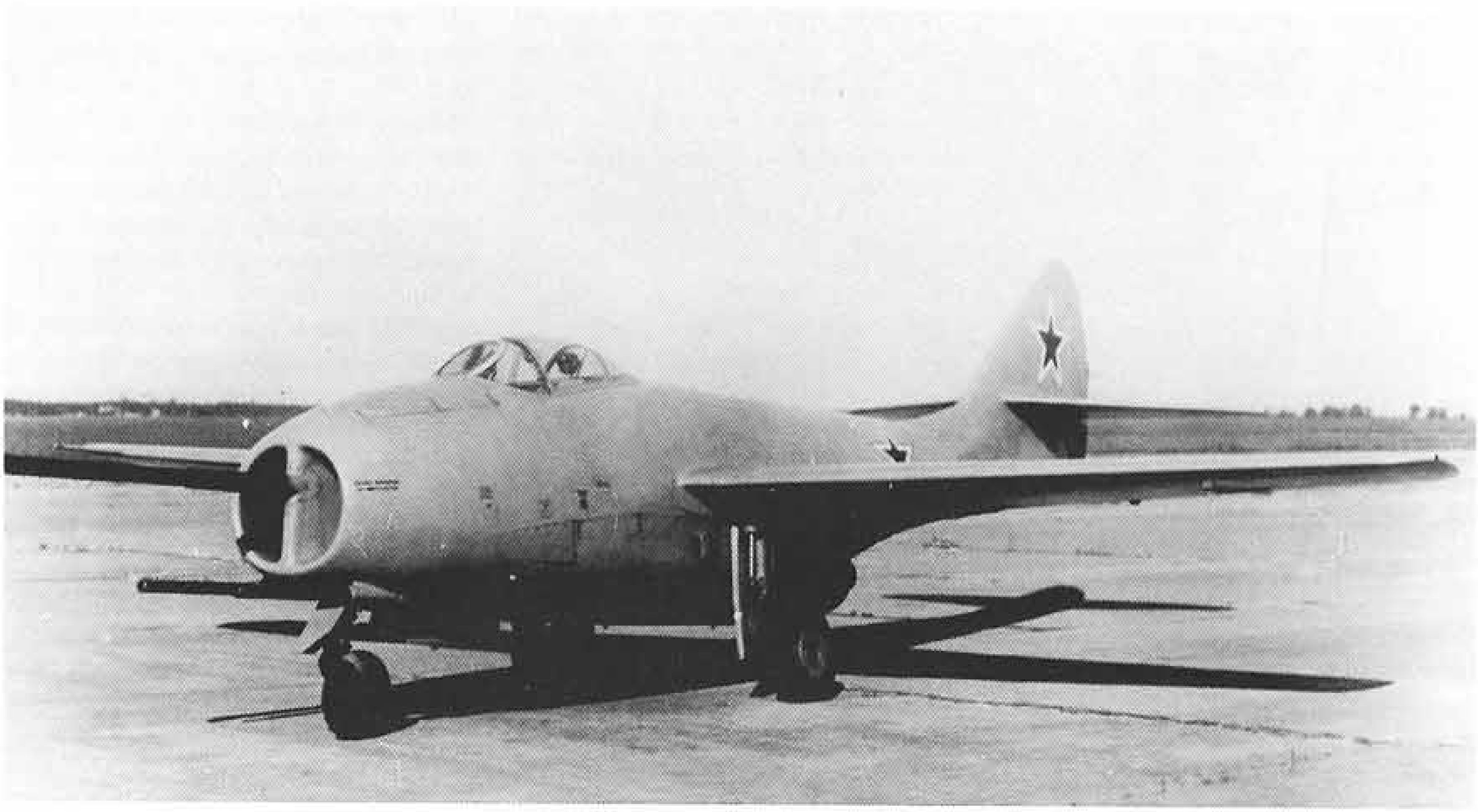
Again a modified series MiG-9, this aircraft had improved protection and uprated RD-21 (originally called RD-20F) engines, as described for the FR,



MiG-9M. (OKB)



I-302, FP. (Yefim Gordon archive)



I-307, FF. (Yefim Gordon archive)

MiG-9M. The increased protection comprised 12mm armour at the front and rear of the cockpit, with a total weight of 60kg (132lb) and a 44mm bulletproof windscreen. This is puzzling, because all series MiG-9s had 12mm armour and a windscreen thickness of 55mm! The wheel brakes were also improved.

I T Ivashchenko made the first flight in September 1947. One FF was fitted with a *Babochka* (butterfly) blast deflector on the N-37 gun. The deflector comprised two vertical rectangular plates behind the muzzle. These caught most of the muzzle gas and curved joins expelled them above and below the inlets. Tests in December 1948 showed that improvement was minimal, and also that the plates increased drag and reduced directional stability, making aiming difficult.

Dimensions unchanged.

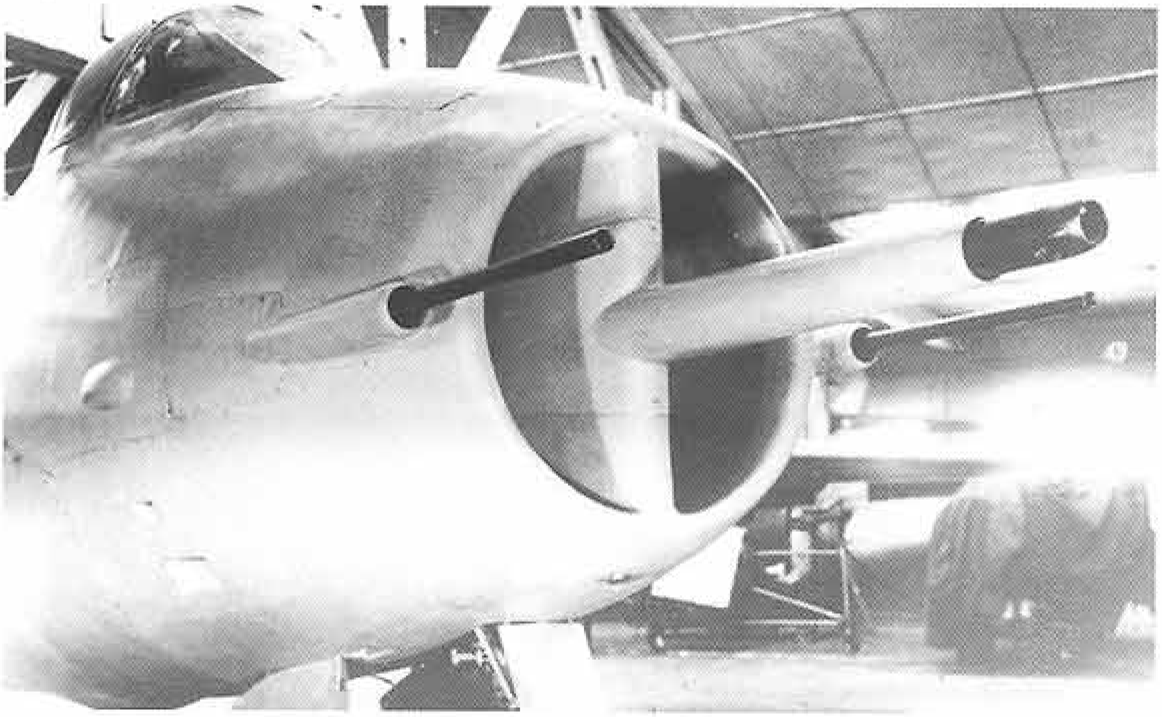
Weight empty 3,471kg (7,652lb); fuel etc 1,309kg (2,886lb); weight loaded 5,117kg (11,281lb).

Maximum speed 950km/h (590mph) at 5,000m (16,404ft), climb to 5,000m 2.9min; service ceiling 13,000m (42,650ft); range 795km (494 miles); takeoff and landing performance, not stated except landing speed 165km/h (102.5mph).

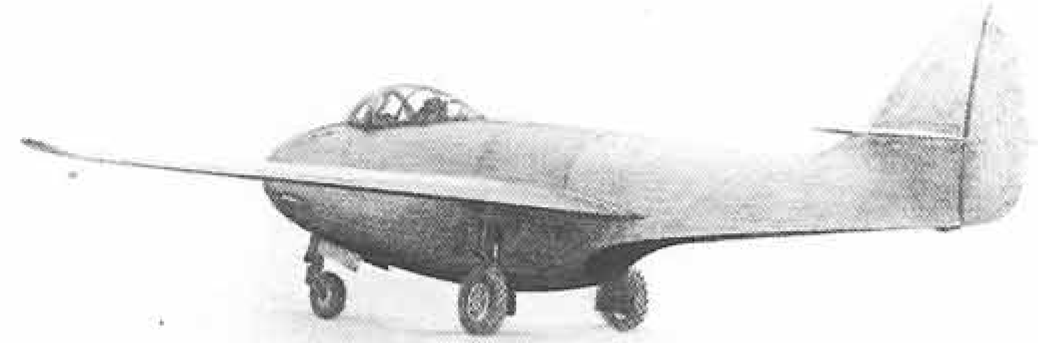
I-305, FL

Throughout the MiG-9 programme the OKB was conscious of the fact that the aircraft was based on engines derived from an enemy design that was fast becoming obsolete. The only available Soviet engine was the TR-1A, derived by A M Lyul'ka from his S-18 of 1945. The TR-1A was qualified in January 1947 at 1,500kg (3,307lb) thrust, and was in all respects superior to the RD-20.

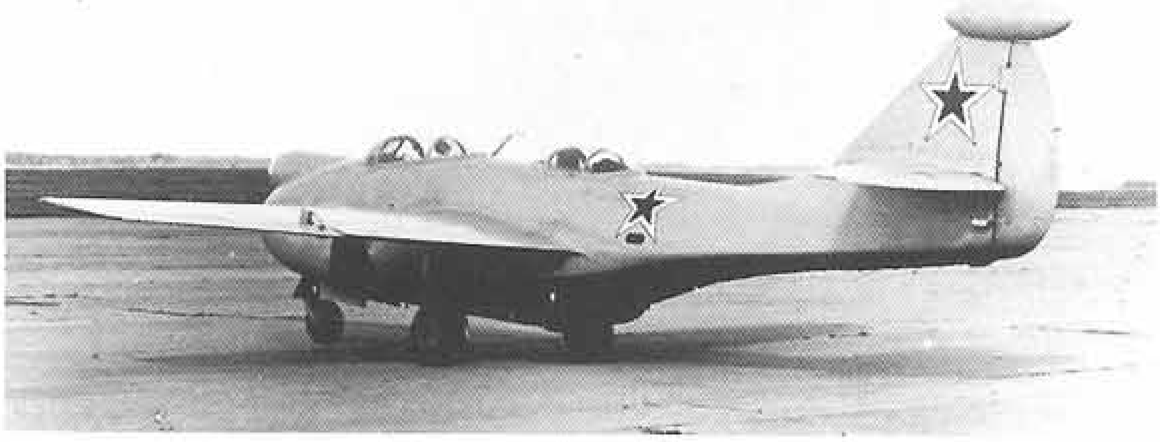
Accordingly, in early 1947 the OKB designed *Izdeliye* FL (L for Lyul'ka), a MiG-9 modified to be powered by a single TR-1A, with



I-305, FL. (OKB)



First project designated I-320. (Yefim Gordon archive)



MiG-9L, FK. (OKB)

capability of eventually accepting an engine boosted by an afterburner to 2,500kg (5,511lb). A mock-up was quickly built and accepted, showing all three guns at the midlevel of the inlet. The N-37 was of a new type designated 120P, with the magazine enlarged to 45 rounds. The I-305 was intended to be fitted with upgraded equipment, including RSIU-10 vhf radio, a *Ton*-3 (tone) direction-finding loop, NI-46 navigation indicator and the new *Bariy* (barium) IFF.

The prototype was almost complete in late 1947 when two things occurred to terminate the programme. The TR-1A earmarked for this aircraft suffered catastrophic failure on the test bench, and the promise of the totally new *Izdeliye* S (prototype MiG-15) made the MiG-9 effectively obsolete.

Dimensions unchanged, except length 9.7m (31ft 10in).

Weight empty 3,055kg (6,735lb); fuel 1,300kg (2,866lb); weight loaded 4,570lb (10,075lb).

Estimated performance: maximum speed 898km/h (558mph) at sea level, 885km/h (550mph) at 5,000m (16,404ft); climb to 5,000m 4.86min, to 10,000m (32,808ft) 13.24min; service ceiling 13,400m (43,963ft); range 1,050km (652 miles); takeoff run 815m (2,674ft); landing speed 155km/h (96mph); landing run 665m (2,182ft).

I-320, FN

Yet another way of re-engining the MiG-9 was to fit a Rolls-Royce Nene. This centrifugal turbojet was rated at 2,268kg (5,000lb) thrust, considerably more than the pair of RD-20 engines, and despite its diameter of 1.26m (49.5in) there was no difficulty in accommodating it. *Izdeliye* FN (N for Nene) was designed very quickly in parallel with the FL, and apart from having a longer fuselage introduced yet another arrangement of the three guns. The N-37 was mounted under the nose immediately to the right of the nosewheel bay and the NS-23s were placed low on each side, all three guns being much further back than before so that the muzzles were behind the inlet.

The prototype was abandoned while under construction in late 1947, because it was clearly overtaken by the Aircraft S. Its designation, I-320, was transferred to a twin-engined radar-equipped interceptor.

Dimensions unchanged except length 10.88m (35ft 8⅜in). No other data available.

MiG-9L, FK

In 1948 OKB-155 was assigned the design and development of the Soviet Union's first cruise missile. This weapon, the KS-1 *Komet*, was to be a radar-homing antiship weapon, to be carried in the first instance by the Tu-4, and later by the Tu-16. To test the guidance system a series MiG-9 was considerably modified, the armament and armour being removed and the missile's complete guidance system being installed. As in the *Komet*, the missile's radar transmitter was mounted above the nose inlet, and a receiver antenna was installed on the leading edge of each wing. On the fin was mounted a pod housing transmitting and receiving antennas for developing the guidance systems of both the missile and the launch aircraft. The system was managed by an operator in an unpressurized rear cockpit.

Aircraft FK (K for *Komet*) was intensively tested in 1949, the parent aircraft being a Tu-4LL. It was subsequently modified with later guidance systems and used to assist development of other weapons, notably the Kh-20 (in Russian, X-20). Details of these missiles appear in the 'Guided Missiles' section and Appendix 2.

Dimensions unchanged except length 10.12m (33ft 2in). No other data available.

I-310, S-01, S-02

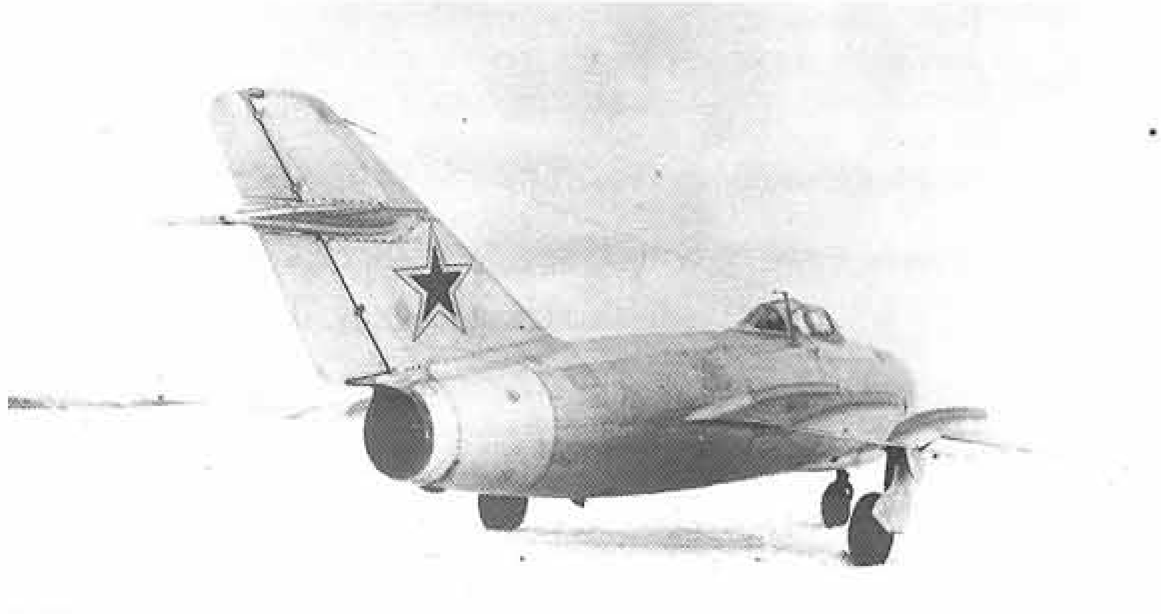
Aircraft S was to prove the turning point not only in the OKB's fortunes but even in the perception of Soviet aviation by the outside world. A classic design by any standard, it was to enter service as the MiG-15, and was to be built in quantities far larger than any previous MiG design, catapulting this OKB into the very front rank of Soviet design teams. The aircraft was also to prove a salutary shock to Western air forces, which from November 1950 encountered it over North Korea. Ironically, it was made possible by a British engine.

In March 1946, before even the first F (MiG-9 prototype) had flown, established Soviet fighter designers were called to the Kremlin. They were told to produce a day interceptor, capable of good manoeuvrability 'up to a Mach number not less than 0.9 and an altitude not less than 11km' (36,089ft), with an endurance of at least one hour, the ability to operate from unpaved airstrips, heavy big-gun armament and easy maintenance.

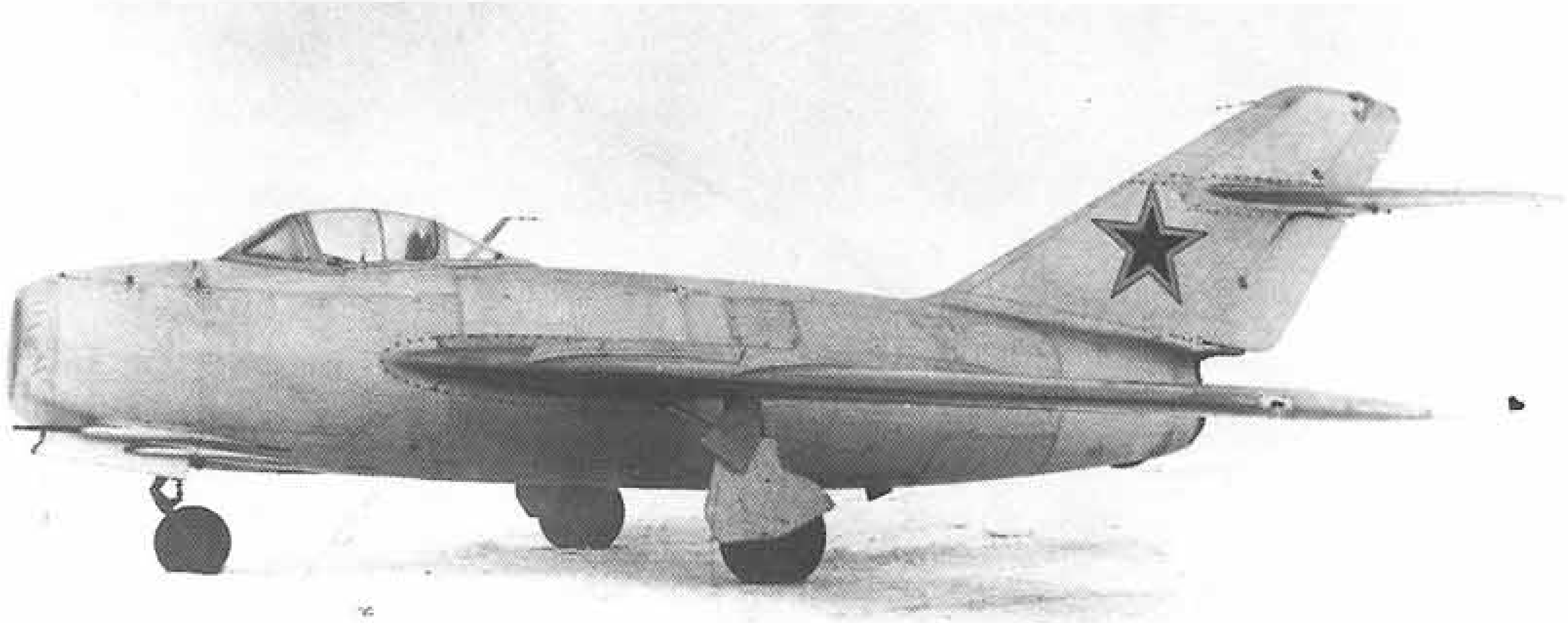
Mikoyan immediately assigned the strongest team he could collect to work on the design of an aircraft, *Izdeliye* S, to meet this demand. The Mach 0.9+ requirement was considered to demand a new aerodynamic shape. Moreover, there was no point in going further with the German-derived RD-10 and RD-20 engines, which were considered obsolescent, and the demand for endurance ruled out a rocket, so the project hinged on the availability of a much more powerful turbojet.

No such engine was under development in the Soviet Union. The only turbojet design team with any experience was that of Arkhip M Lyul'ka, whose TR-1A lacked the thrust needed, and was in any case years away from production. One possibility appeared to be the use of a wartime BMW design aimed at 2,000kg (4,410lb) thrust. This engine had never been built, but was adopted by the French and produced as the prototype Atar. Among engines that had actually run, the most powerful in the world was the British Rolls-Royce Nene, of 2,268kg (5,000lb) thrust. Mikoyan and Maj-Gen V Ya Klimov, whose engines had powered two-thirds of the wartime Soviet fighters, spent hours carefully examining the Nene displayed at the Farnborough airshow at the end of June 1946. Though a large-diameter centrifugal-compressor engine, it was so simple and robust that it seemed the ideal choice.

Mikoyan told his designers to base their S project on a copy of the British engine. This copy of the Nene was urgently worked on by Klimov's engine KB. It was called VK-1PO, from 'Vladimir Klimov 1st consignment'. Soviet intelligence confidently expected to obtain drawings and vital details of the British engine before the end of 1946, but immediately after the Kremlin meeting an easier answer presented itself.



I-310, S-01. (OKB)



I-310, S-01. (OKB)

The two most senior men in the Soviet aircraft industry were Mikhail V Khrunichev, a distinguished VVS pilot who had just been appointed minister, and the deputy minister and famous aircraft designer Aleksandr S Yakovlev. They suggested to Stalin a direct request to the British government for the purchase of Rolls-Royce Derwent and Nene engines. Stalin retorted 'What fool will sell us his secrets?' The answer proved to be 'A British fool'. Britain had a Labour government, and the responsible minister, Sir Stafford Cripps, immediately gave his assent to the deal, even though no use was being made of the Nene for any RAF aircraft. With the benefit of hindsight this is hard to believe!

Within a week a delegation had left for London, from where it moved to the Rolls-Royce works at Derby, one member of this team being Mikoyan. In early September 1946 they returned to Moscow with a signed contract for thirty Derwents and twenty-five Nenes, ten Nenes actually accompanying the delegation on their return journey. To say these engines were put to instant use would be an understatement. Two were at once put to static testing on the bench at CIAM, three were assigned to flight testing under a Tu-2LL (actually designated Tu-2N, from the test engine), four were dismantled and subjected to detailed engineering and metallurgical inspection, and the tenth was used as the mock-up by the MiG OKB. This enabled the MiG-15 to go into production approximately 18 months earlier than would otherwise have been possible.

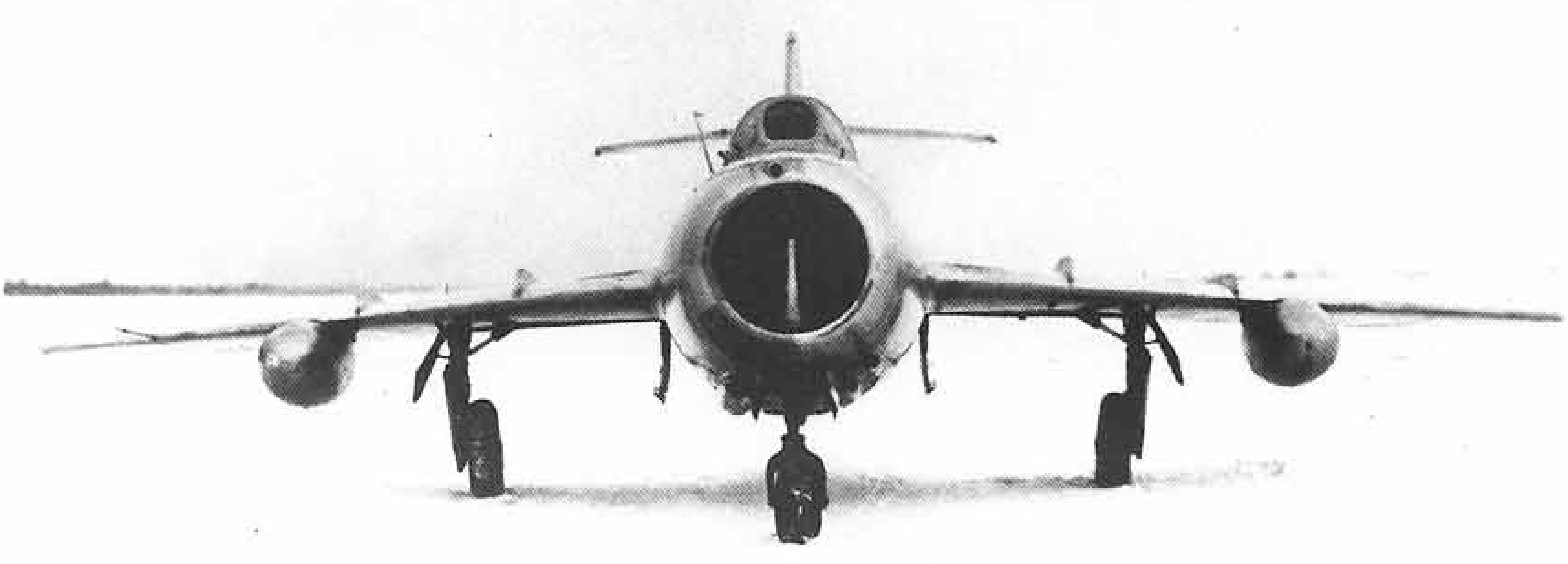
Of course, the VK-1PO was abandoned and, without attempting to obtain a licence or even to inform the British, plans were hastened to put the Nene into production. The factory chosen was Factory No. 45 in Moscow. Klimov's team at Factory No. 117 in Leningrad simply called the British engine the RD-45 (RD meaning jet engine as before, plus the number of the production factory). The first of Klimov's design engineers detailed to assist Factory No. 45 was sent to Moscow on 21 September 1946, and the first RD-45 production drawings were issued on 30 October. The MiG OKB received a complete set of RD-45 installation drawings in February 1947, removing almost the last hold-up in the design process.

This still left the thorny question of what shape to make this potentially vital aircraft. Soviet designers had urgently studied German literature on wings swept forwards and back, and had also made tunnel tests with models of these configurations, as well as tailless deltas. Instrumented models were dropped from a Tu-2, and several contracts were placed for aerodynamic research aircraft. CAHI aerodynamicists brought in to assist the OKB included S A Khristianovich, G P Svischyov, Ya M Serebriyskiy and V V Struminskiy. Some aerodynamicists pointed to German troubles with swept wings, and to the adoption of the straight-wing Yak-23 for production, but the successful testing of the La-160 on 24 June 1947 showed that a 35° swept wing and tailplane could be flown safely, so this configuration was adopted. In fact, by June 1947 the OKB was already issuing drawings for Aircraft S with a 35° swept wing.

Studies with the engine near the centre of gravity, with the jet nozzle near the wing trailing edge as in the MiG-9, met with few supporters. Accordingly, a cigar-shaped fuselage of minimum frontal area was adopted, with a circular section dictated by the diameter of the engine of 1,257mm (49.5in), which in fact matched well with the size of pressurized cockpit needed. The engine was installed in the simplest possible manner with a plain inlet in the nose and the shortest practical jetpipe discharging at the tail.

The wing was mounted in the mid position, so one of the few design choices was whether to attach left and right wings to strong fuselage frames or to spars bridging the fuselage (a matter ignored in all previous MiG books!). The wings and tail were swept, the cockpit was placed ahead of the main fuselage fuel tank and, because there was no room in the fuselage, the main landing gear was housed in the wings. No attempt was made to put fuel in the wings. The entire airframe, including control surfaces, was metal-skinned, and it was designed to the exceptional load factor of 8g.

The result looked exceedingly neat and compact, and formed an interesting comparison with its great rival, the North American XP-86 (later F-86) Sabre. The US aircraft, the only other swept-wing fighter to fly before 1948, had a wing of closely similar aerodynamics but mounted in the low position. This enabled the main landing gear to be shorter and the engine air duct to be unimpeded by spars. Mikoyan's team selected the mid-mounted wing because this is the optimum aerodynamically.

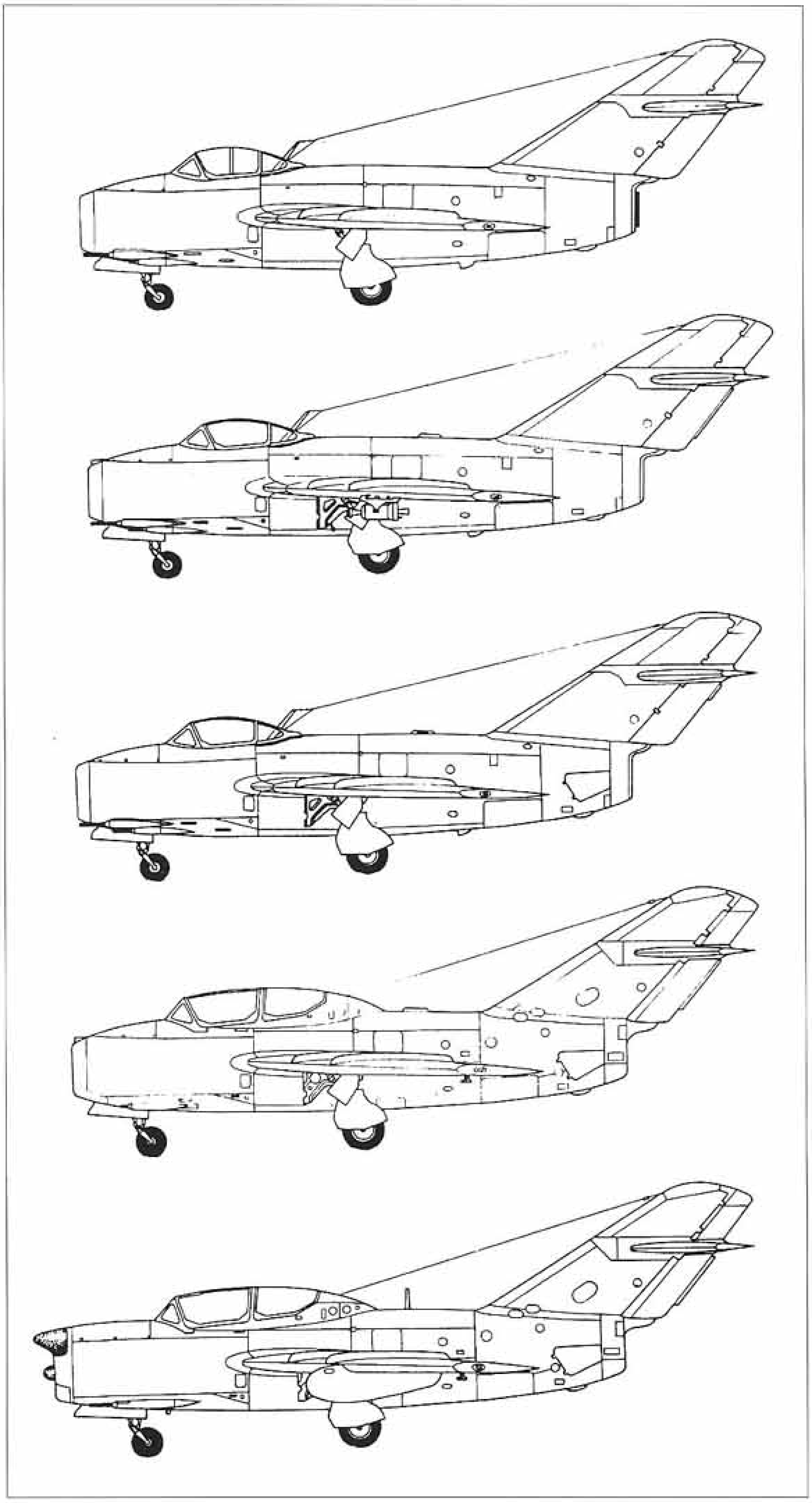


S-02. (OKB)

The wing profile chosen was S-10s at the root, changing well outboard to high-lift SR-3 at the tips, thickness/chord ratio being 11 per cent throughout. At the quarter-chord line the sweepback was 35°, a value which became almost universal for fighters of the 1950s. Taper ratio was 1.61, and the mean aerodynamic chord of 2,120mm (83.46in) gave an aspect ratio of 4.85. At rest the wing was attached with anhedral of –2°. From late 1945 CAHI had studied swept-wing aerodynamics, and Struminskiy had investigated the optimum design of fences (low walls parallel to the fuselage) to minimize outward flow over the upper surface. With his help each wing was fitted with two full-chord fences with a height of 100mm (3.94in).

Structurally each wing comprised widely separated main and rear spars, two transverse beams at 90° to the aircraft centreline (the front one quite short and stopping at the wing root), 21 spanwise stringers and 20 ribs at 90° to the leading edge. The tip was detachable, secured by screws and anchor nuts to Rib 20. The skin, applied in inboard, centre and large outboard sheets wrapped round the leading edge, was 1mm thick except between the spars where the thickness was 2mm. The ruling material was D-16T except for the spar booms, which were V95 steel.

The fuselage had a maximum diameter of 1.45m (57⅒in), length of 8.125m (26ft 7⅞in), fineness ratio of 5.57 and frontal area of 1.16sq m (1.35sq m, 14.53sq ft, including the canopy). It was made in front and rear sections, bolted together at Frames 13/13A. Frame 1 incorporated the nose splitter which separated the engine air supply along left/right ducts with a cross-section formed from two circular arcs. These ran along each side of the fuselage past the cockpit and main tank to terminate at Frame 13 where the air simply poured into the plenum chamber containing the engine. There were four main longerons and various stringers, attached to the frames by small steel brackets.



From the top: S-01; S-02; MiG-15 first series; UTI MiG-15; UTI MiG-15P (see *p.68*).

Frames 9 and 13 incorporated extremely strong transverse beams of V95 and 30KhGSA, faired by thin sheet above and below to improve airflow to the engine. Each beam terminated at each end in upper and lower trunnions to which each wing spar was attached by precision bolts of high-tensile steel. After the wing was attached, the wing/fuselage joint was faired by a wrap-round fillet secured by screws and anchor nuts. The engine was carried off Frame 13 by a truss of welded 30KhGSA tubes terminating in four antivibration mounts which picked up trunnions on the compressor casing.

The engine was a Nene 1, rated at 5,000lb in Britain but by the Russians at 2,230kg (4,916lb). It was housed in the front of the rear fuselage, which after undoing four bolts and making various disconnections could be removed on a dolly to expose the complete engine and cantilevered jetpipe. The front part of the rear fuselage, terminating at a bulkhead at Frame 20 (roughly in line with the engine turbine), formed a plenum chamber to which air was delivered by the ducts in the forward fuselage. The rear fuselage comprised Frames 13A to 28, joined by 20 stringers, plus an additional sharply sloping frame integral with the main spar of the lower fin, which was constructed integral with the rear fuselage.

Unlike any structure the OKB had seen before, the tail comprised a very large (4.0sq m, 43.06sq ft) vertical tail with no less than 56° sweep on the leading edge, with a main spar of 30KhGSA on which, 1,582mm (62.3in) above the fuselage centreline, a forged bracket carried the tailplane, which was also attached near its leading edge to the second of the five secondary spars ahead of the main spar in the lower fin. Above the tailplane was a round-topped upper fin, attached by screws and anchor nuts. Area of the horizontal tail (complete) was 3sq m (32.29sq ft), its span being 3.25m (10ft 8in) and leading-edge sweep 35°, later increased to 40°.

All flight-control surfaces were wholly manual in operation and of entirely D-16T construction, skin thickness being 0.8mm (0.0315in) throughout. All were driven by rods, levers and bellcranks. The ailerons incorporated large balance areas ahead of the hinge which projected inside the wing where they were sealed by fabric strips. Ahead of the port aileron was a UT-6D electric motor connected via a screwjack and linkage to a trim tab. A similar drive was provided for a trim tab on the port elevator, both elevators being operated by a push/pull rod behind the fin main spar. A similar drive was provided for the bottom of the lower rudder, at the top of which a cardan shaft drove the upper rudder in unison. The upper rudder incorporated a lead antiflutter mass ahead of its tip, and an antiflutter mass was built into the leading edge of each wing inboard of Rib 20.

Each wing was fitted with a one-piece Fowler flap (called CAHI-type in the Soviet Union) running out on three tracks attached behind the rear spar. Each had an area of 2.36sq m (25.4sq ft), and was entirely of D-16T with 19 ribs and an upper skin covered with large circular perforations. Flap chord was constant, though the trailing edge of the wing curved round towards the root to meet the fuselage at 90°. The flaps were driven by individual hydraulic jacks, but linked by cables to ensure symmetric operation. They were extended to 55° for landing.

Designed at the OKB, the tricycle landing gear was particularly neat. Each unit comprised a single leg carrying the wheel on a levered-suspension arm which multiplied the stroke of the air/oil oleo cylinder. The freely castoring nosewheel was fitted with a 480 × 200mm tyre and a shimmy damper. It was pivoted to a trunnion on the front face of Frame 4, which was the front pressure bulkhead of the cockpit. A vertical hydraulic cylinder on the front face of this bulkhead pulled the unit forwards into a bay between the inlet ducts, sealed by two doors which remained open when the unit was extended.

Each main landing-gear unit terminated at the top in a large horizontal tube which rotated in bearings in trunnions bolted in the angle between the front spar and the large rear transverse beam. A long-stroke hydraulic jack pulled the unit inwards, while the levered wheel arm rotated to shorten the unit to fit in the bay between the two transverse beams immediately outboard of the fuselage. The retracted gear was faired by two doors moving with the leg and a third hinged under the wing root. Each wheel was fitted with a simple drum brake and 660 × 160mm tyre. All three landing-gear units could in emergency be extended by the standby pneumatic system. In addition to the cockpit indicator, confirmation that each main unit had extended was provided by a mechanical indicator projecting above the wing. Wheelbase was 3,075mm (10ft 1in), and the track was an impressive 3,852mm (12ft 7.7in); narrow track was a fault of the MiG's only rival, the La-15.

The engine was supplied with a British Rotax electric starter and Lucas fuel pump and ignition system, but other equipment was Russian. The principal indigenous item was the hydraulic pump, serving a system filled with the usual Soviet alcohol/glycerine mixture, with a cut-out pressure of 13.7MPa (1,987lb/sq in). The system served the landing gear and flaps, and was later to drive air-brakes and aileron boosters.

In addition, the engine drove an air compressor to recharge high-pressure bottles serving Main and Emergency pneumatic systems. The main (or primary) system energized the wheel brakes and the rams for cocking the guns, and together with compressor bleed supplied the pressure air serving the cockpit environmental system. The Emergency (or standby) system was provided to jettison the canopy, lower the flaps and landing gear in the event of hydraulic failure, and, in parallel with the primary system, it could apply the wheel brakes.

The simple single-wire electrical system was energized by a Rotax 28V d.c. generator, which charged a Soviet 12A-30 battery in the top of the nose. It served cockpit and navigation lighting, the electrically driven instruments, control of most systems including armament, and the RSI-6 vhf radio, which was the only avionics item carried by the S-01.

The fuel system was particularly simple and comprised a large protected flexible cell (called Tank 1) behind the cockpit, between Frames 9 and 13, and a smaller aluminium tank (divided into left and right sections called Tanks 2 and 3) wrapped round the underside of the jetpipe between Frames 21 and 25. Total capacity was 1,538 litres (338gal). Further details of the fuel system are given for the production aircraft.

One of the pioneering features was the armament. From the outset this had been planned to be basically the same as that on other Soviet interceptors such as the MiG-9, namely an N-37D with 40 rounds on the lower right side of the nose and two NS-23KM guns each with 80 rounds in the corresponding position of the left, all three barrels lying in the same horizontal plane. While the S-01 prototype was being built, testing the guns in MiG-9 prototypes caused dangerous engine flameouts, and for a time work on the S-01 was actually halted. Armament designer N I Volkov was urgently called to the OKB, but engine specialists correctly predicted that the British engine's centrifugal compressor would be much less bothered by fluctuations in the air supply than the tricky axial compressors of the German-derived engines.

Volkov did, however, come up with a brainwave. He proposed that the three guns and their magazines should be mounted on a removable tray, which could be quickly winched up into the fuselage. When removed from the aircraft the tray gave all-round access to the guns, magazines and feed guideways, boxes for empty cases and the ejection chutes for spent links. To install it in the aircraft the complete pack was attached to four cables which were then wound up on reels driven in unison by shafts geared to a hand crank. Once fully home, the pack was locked in place, the barrel fairings screwed back in place and the guns connected to their compressed-air and electrical controls. Tests showed that the pack could be lowered, the magazines replaced and the pack raised in three minutes. Three years later a similar scheme was designed for the Hawker Hunter.

While S-01 was being built, the MAI was making static tests on a representative wing, because there was no established body of data for the strength of swept wings. The first wing did not fail until 120 per cent of the design load. A second wing was then tested, with skin thickness and other parts made thinner, saving 180kg (397lb). This failed at only 70 per cent. Strengthening the point of failure added only 18kg (40lb), and the wing then failed at 100 per cent. Wings to the final standard were then made for S-01 and -02.

S-01 was completed on 27 November 1947, two months after the American XP-86 but almost four years before any British equivalent (Hunter, July 1951; Swift, August 1951). It was handed to Konstantin Kovalevskiy, OKB director of flight test for Aircraft S, who had it taken to the LII at Zhukovskiy. The only problem was the severe winter weather, and even though it meant slipping behind the schedule the decision was taken to delay the first flight until the spring of 1948. However, the assigned OKB pilot Viktor N Yuganov considered S-01 to be a much safer proposition than the aircraft he had been flying (the I-270) and in any case he was eager to receive the first-flight fee of 10,000 roubles. On 30 December, despite a 2km (about 6,500ft) cloud base, he took off and flew two circuits. When informed by telephone, Mikoyan sent his congratulations.

On the whole the new prototype flew excellently, but significant losses in thrust were recorded (it is not known how, because thrust cannot be measured in flight). Ing Kalikhman and his team from CIAM recommended shortening the jetpipe and rear fuselage, together with changes to the wing chord, ailerons, tail sweepback and all control surfaces. The published record is confusing, and the only changes actually made – initially in S-02 – appear to have been to install a Nene 2 engine, rated at 2,270kg (5,004lb), shorten the jetpipe by 320mm (12.6in), increase the area of the ailerons by extending their chord at the leading edge, and fit a one-piece canopy (eliminating the narrow metal frame at midlength), provision for two 250lit (55gal) slipper tanks under the wings, an ASP-1N optical sight and an S-13 combat cine camera above the nose.

S-02 was taken to the NII-VVS at Chkalovskoye and first flown there on 27 May 1948, the pilot being Col Gregoriy Sedov. A second NII-VVS pilot assigned to the I-310 was Yu A Antipov, A G Kochetkov being assigned to the rival La-15. State trials, which also involved S-01, were made in two stages, the first being completed on 25 August and the second between 4 November and 5 December 1948.

At the completion of the first stage of NII-VVS trials the Council of Ministers decided to put the I-310 into production, with the designation MiG-15. By this time the improved S-03 prototype was also flying, and the general opinion was that the I-310 was the best fighter in the world. In December 1948 VVS Commander Marshal K Vershinin signed an order for the MiG-15 to be introduced into the inventory.

Despite this, the NII-VVS continued to evaluate the MiG aircraft against the La-15, which though much less powerful was lighter (and cheaper) yet had a similar performance. The evaluation included spinning, which in these swept-back high-tailplane aircraft could be unpredictable and possibly dangerous. Accordingly, S-02 was equipped with small rockets under the wings which could be fired individually to assist spin recovery. Despite this, during inverted spin tests NII-VVS test pilot Bogdanov was killed in this aircraft.

In the event, the La-15 was also ordered into production, with the expectation that VVS service would soon show one of the rival fighters to be superior. This proved to be the case, production of the Lavochkin aircraft soon being terminated. The following data refer to S-01.

Span 10.085m (33ft 1in); length (excluding guns) 10.102m (33ft 1¼in); wing area 20.60sq m (221.75sq ft).

Weight empty 3,380kg (7,451lb); fuel 1,245kg (2,745lb); oil 35kg (77lb); weight loaded 4,820kg (10,626lb).

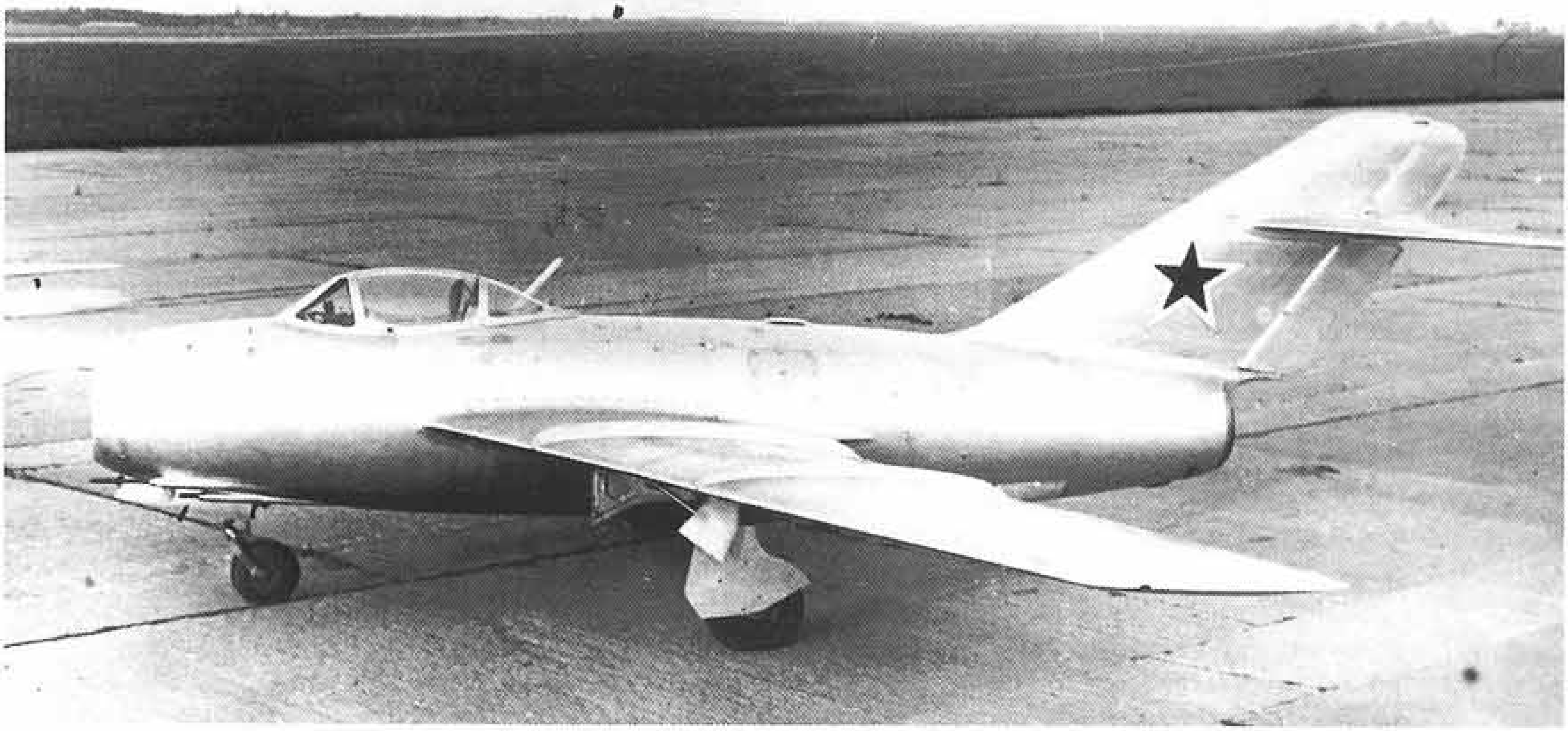
Maximum speed 905km/h (562mph) at sea level, 1,042km/h (647.5mph) at 3,000m (9,842ft); climb to 5,000m (16,404ft) 2.3min, to 10,000m (32,808ft) 7.1min; service ceiling 15,200m (49,870ft); range cruising at 12,000m (39,370ft) 1,395km (867 miles); takeoff run 725m (2,379ft); landing speed 160km/h (99.4mph); landing run/765m (2,510ft).

S-03

The third prototype was added to the programme in February 1948, when S-01 flight test results had shown the need for various changes. S-03 was regarded as the preproduction prototype, though it still had to be powered by a Nene II engine. Chief engineer on the aircraft was A G Brunov, and the OKB test pilots assigned to it were K P Kovalevskiy and N V Zaikin.

The most significant change was to restress the wing to meet new standards of structural strength introduced in 1947. Without altering the aerodynamics, the ruling material was changed from D-16T to V-95, giving a gain in ultimate strength of some 20 per cent, and the entire structure of each spar was now in 30KhGSA. Skin thickness was increased from 1.5 to 1.8mm, and the rib spacing was reduced to accommodate twenty-three ribs in each wing instead of twenty. These changes added 180kg (397lb) to the weight of the combined port and starboard wings. Whereas limit load factor for S-01 (and presumably S-02) was 8.0, the figure stipulated for S-03 was 8.02, despite the more severe requirements.

None of this was externally obvious, but careful inspection would have shown that further changes had been made to the ailerons and flaps. The area of each aileron was again increased, from 0.96sq m (10.33sq ft) to 1.17sq m (12.59sq ft), mainly by extending the span inboard. This reduced the span of the flaps, whose area was restored by increasing the chord. S-03 was the first MiG aircraft



S-03 (airbrake not visible). (OKB)

to use flap on takeoff, a new 20° setting being provided for this purpose. This reduced takeoff run at maximum weight by some 115m (377ft) from the 810m measured with S-02 (why S-02 should have needed such a long run has not been explained, the figure for S-01 being 725m).

The chief visible modification was to add a door-type airbrake on each side of the rear fuselage. This was done in order to be able to decelerate rapidly in flight, and also facilitate formation flying; the airbrakes had little effect on landing run. Each brake had a trapezoidal shape, tapering from front to rear and hinged about a leading edge inclined at 30° to the vertical. A large part of the rear fuselage had to be reinforced to carry the loads from the hinges on Frame 25 and from the single hydraulic jack used to open each brake to 55°. Area of each surface was 0.52sq m (5.597sq ft).

S-03 in assembly in OKB-155. (OKB)

A modification which ought to have been immediately obvious, but which cannot be detected in photographs, was to move the tailplane 150mm (5.9in) to the rear to increase its moment arm. This required corresponding modification to the fin. The elevators were fitted with new balance (antiflutter) weights, though again this cannot be detected in photographs.

Some sources state that fuel capacity was increased, but in fact it was reduced. The capacity of Tank 1 was increased while that of Tank 3 was reduced, the net effect being a loss of 88 litres, from 1,538 to 1,450 litres (319gal). Each wing was not only plumbed for slipper tanks, as was S-02, but fitted with universal attachments for drop tanks of capacities 250, 300, 400 or 600 litres (55, 66, 88 or 132gal) or bombs of types FAB-50 (high explosive, 50kg, 110.2lb), FAB-100 or AO-25 (container or fragmentation bombs).

Changes to the armament included addition of a flash eliminator to the N-37D gun, redesign of the gun barrel fairings so that they could be quickly unclipped or replaced when lowering or raising the gun pack, and installation of the improved ASP-1N sight. Other changes included addition of an automatic no-load running valve in the hydraulic system, and of a fire warning and extinguishing system in the engine bay. S-03 is believed to have been the first Soviet fighter with a fire extinguishing system.

The first flight was made on 17 June 1948 by OKB pilot Ivan T Ivashchenko. Soon assisted by LII pilot Sergei N Anokhin, he eradicated all identified shortcomings in 48 flights, ending on 15 October 1948. The highest Mach number reached during factory testing was 0.934. On 1 November 1948 S-03 was flown to NII-VVS trials, which because of the onset of winter were held at Saki, Crimea. This State testing was completed on 3 December in 35 flights totalling 15 hours 21 minutes.

Among the conclusions in the NII-VVS report were that the I-310 could be flown by pilots of average ability, could be operated from rough strips, and could be flown in sustained inverted flight. Though no mock dogfighting had been attempted, this fighter was expected to excel in close combat. As noted previously, on completion of these trials Marshal Vershinin signed the production order for what was to be the MiG-15.

The following data refer to S-03. The empty weight figure of 2,955kg given in several sources is difficult to believe, in view of the fact that every modification made to this third aircraft increased its empty weight over its predecessors. The figure given below is that published by Shavrov.

Dimensions unchanged.

Weight empty 3,382kg (7,456lb); fuel 1,210kg (2,668lb); oil 40kg (88lb); weight loaded 4,806kg (10,595lb).

Maximum speed 905km/h as before at sea level [V B Shavrov states 1,050], 1,031km/h (641mph) at 3,000m (9,842ft), 983km/h (611mph) at 10,000m (32,808ft); climb [Shavrov] to 5,000m (16,404ft) 2.3min, to 10,000m (32,808ft) 7.1min; service ceiling 15,200m (49,870ft) as before; range 660km (410 miles) at 1,000m (3,280ft), 908km (564 miles) at 5,000m (16,404ft), 1,433km (890 miles) at 12,000m (39,370ft) [Shavrov, 1,420km]; takeoff run 695m (2,280ft) [Shavrov, 600m]; landing speed 160km/h as before; landing run 710m (2,329ft).

MiG-15, SV

Much confusion has surrounded the entry into production of the MiG-15. To clear up some of the problems, all early production aircraft were *Izdeliye* SV, not S; the first production engine was the RD-45F, not RD-45; and, though even official documents give different dates, the first production MiG-15 (No. 101003) made its first flight at Factory No. 1, the original MiG factory which after the war had remained at Kuibyshev, on 30 December 1948, a year to the day after the first flight of S-01.

The initial authorization for production had followed the decision of the Council of Ministers back in the preceding August, otherwise the first series aircraft could not have flown in December. However, the crucial document was that calling for the MiG-15 to be issued to front-line units of the VVS, signed by the supreme commander, Marshal Konstantin A Vershinin, on 23 December 1948, a week before the first flight of a series aircraft. Production planning, managed for the OKB by one of its founders, Vladimir A Romodin, was well advanced when the details of the programme were confirmed by the Council of Ministers on 20 May 1949. For the first time (except during the Great Patriotic War) the programme involved four large factories, which were to produce MiG-15 aircraft for Frontal Aviation (tactical air forces), the IA-PVO (air defence interceptors), A-VMF (naval air force) and export. Production totals are given later.

Manufacture of airframes built up in parallel with production of the RD-45F engine, which gradually became available from the beginning of 1948. (Thanks to brilliant work by Klimov's team a more powerful version, the VK-1, was put into production at almost the same time, as related later.) The RD-45F was rated at 2,270kg (5,004lb), and of course was fitted with entirely Soviet accessories, including an electric starter, GS-3000 generator and hydraulic and pneumatic pumps. Though it was a copy of a mature British engine with a TBO (time between overhauls) of 500 hours, the RD-45F was initially lifed at only 100 hours. This was gradually extended as service experience built up.

Even the first series aircraft incorporated numerous detail modifications compared with S-03. These included a further careful analysis of the airframe and more than twenty local structural modifications, either to improve load paths or to increase strength or stiffness. An unexpected piloting problem became evident only with series aircraft, where adherence to manufacturing tolerances was not as rigorous as with the handbuilt prototypes. At high speed some aircraft tended to roll, to left or right. Occasionally an aircraft was found where, at about Mach 0.9, even with the stick hard over the pilot could not keep the wings level!

One answer was to do everything possible to tighten up the tolerances in manufacture – some early aircraft were found to have wing inaccuracies as great as 4mm (0.156in) – so that the port and starboard wings gave equal lift. A second was to modify the wing locally, especially inboard where the underside had a large cutout for the landing gear, to increase torsional stiffness. A third answer was to rivet a thin strip of D-16T, 40mm (1.575in) wide, called a *nozh* (knife), behind the trailing edge from the kink near the root to the aileron. Some aircraft had an additional strip, 30mm (1.18in) wide, riveted behind the right aileron. These strips were then bent with pliers until the aircraft flew wings-level at all speeds. A similar *nozh* was added along the trailing edge of the lower rudder.

A related problem was the combination of rolling, yawing and pitching known as Dutch roll, encountered at high Mach numbers. Not much was known about this in 1949, and the temporary answer adopted was to advise pilots not to exceed Mach 0.88. In mock combat it was difficult to obey this rule, and soon the airbrakes were linked to the air-data circuit so that they were opened automatically at about Mach 0.9.

Early in production remedial action was taken to ensure that the engine was not starved of fuel during negative g or sustained inverted flight (a problem apparently never encountered with the prototypes). Two modifications resulted. The fuel, which from late 1948 was standard T-1 jet-engine kerosene, was fed from the rear tank to the main tank, from where the PTsR-1 electric booster pump fed it to the PNV-2 high-pressure pump on the engine. To ensure a constant supply a small feeder tank was inserted with a feed pipe which swivelled according to the attitude of the aircraft. In steady inverted flight this tank could supply fuel for 10 seconds.

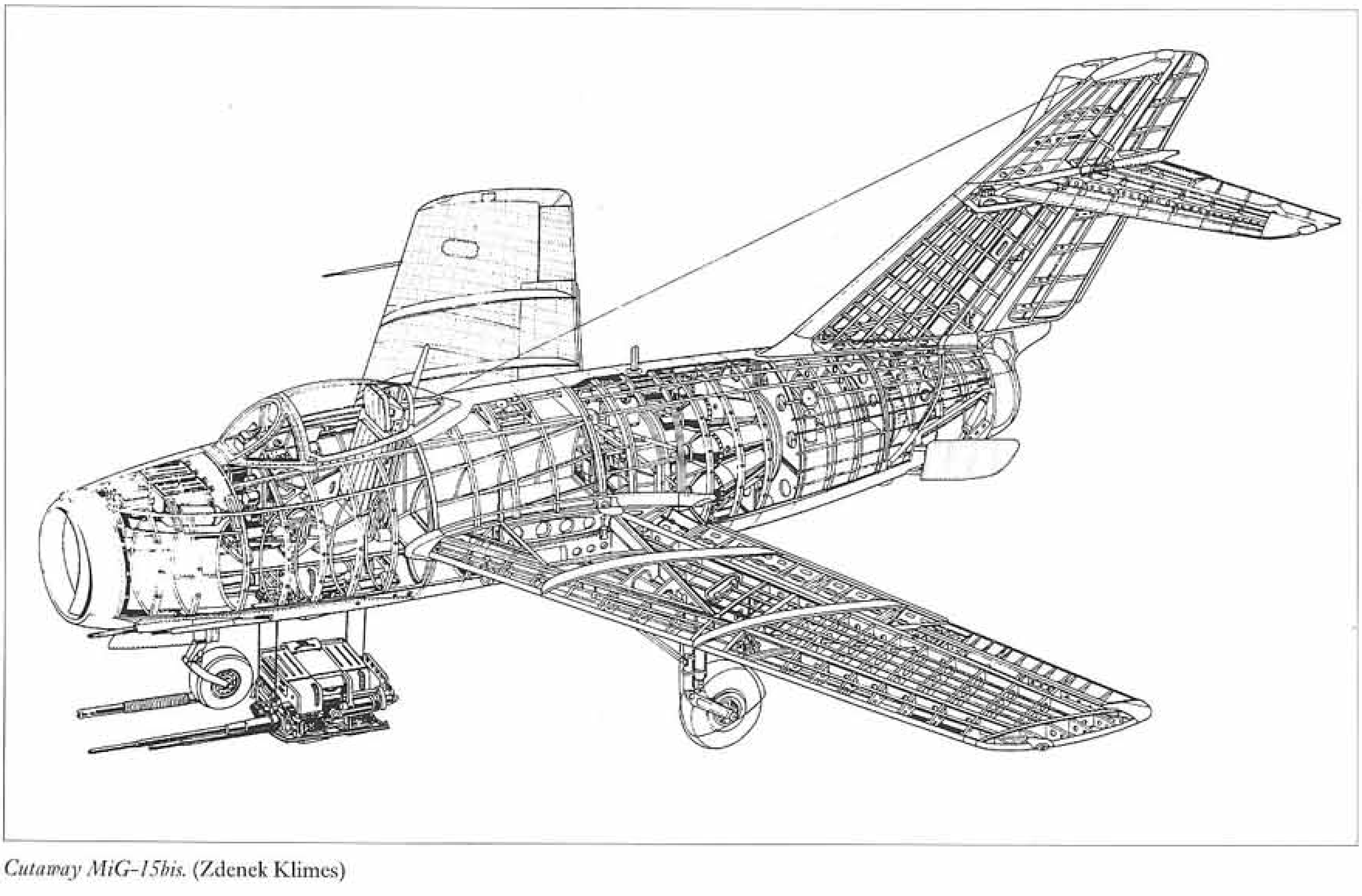
The second modification was to install pipes from which compressed air could be bled from the engine diffuser case to pressurize any external tanks carried (not the aircraft's own tanks). Without such tanks fitted, these pipes were valved off. In any case, for many months after entry into service, aerobatics and combat manoeuvres were prohibited, which took the edge off flying an otherwise exciting aircraft.

In 1947 CAHI had begun development of powered flight controls for high-speed aircraft, and with CAHI assistance a reversible hydraulic actuator, designated B-7, was installed in the fuselage immediately ahead of the main tank to drive the push/pull linkages to the ailerons. This was absent from the first series aircraft, but was fitted retroactively. The B-7 was a booster, not an irreversible power unit, and the pilot retained direct mechanical control in the event of its failure. The power assistance enabled aileron chord to be again increased, to 21 per cent of wing chord.

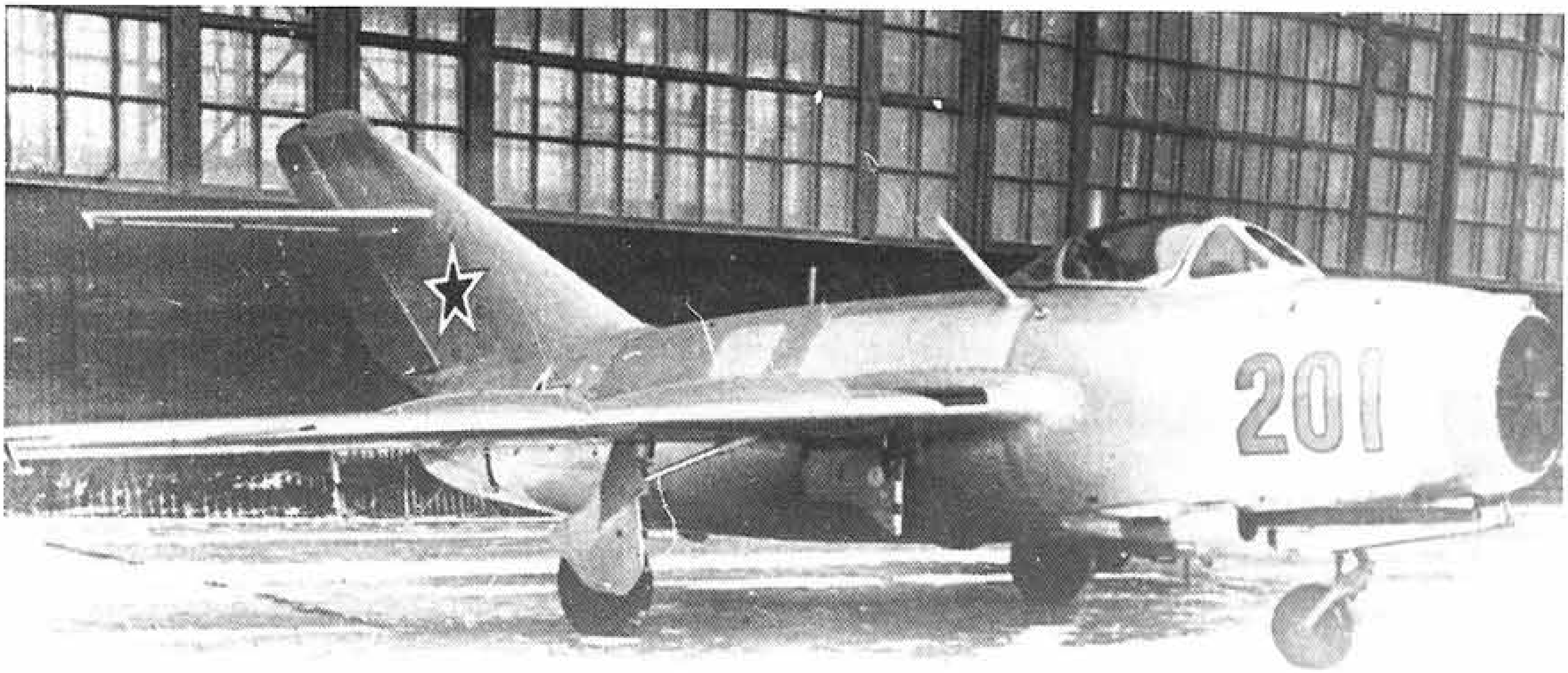
Further modifications were also made to the tail. The leading edges of the elevators and rudders were again altered, and while elevator aerodynamic balance was increased to 18 per cent, reducing stick force, the slot between each elevator and the fin was made narrower. In the course of production a standby cable circuit was added to control the elevators following combat damage to the primary rod linkage.

Several changes were made to the airbrakes. A sharp nose-up moment caused by opening them was eliminated by slight modification to their hinge axis, and the airbrakes themselves were made more rigid by changing their outer skin to El-100N steel. Instead of using a lever the pilot was provided with airbrake control by pushbuttons, one to open the brakes and the other to close them. Early MiG-15s had a forest of pushbutton switches and circuit-breakers on the cockpit side consoles, which pilots called the 'Russian accordion'. Later batches reverted to traditional switches.

Various changes were made to the armament. The N-37D was fitted with an improved muzzle attachment to reduce recoil and minimize bright flames at night, and its mounting was modified to eliminate vibration transmitted to the fuselage. The NS-23KM guns were replaced by the newly developed NR-23, which had a faster cyclic rate (*see* Appendix 2) and could be fed from either side. Their mountings were improved, with no need for the hydraulic dampers previously fitted.



Cutaway MiG-15bis. (Zdenek Klimes)



MiG-15 with two NS-37 guns at LII. (Yefim Gordon archive)

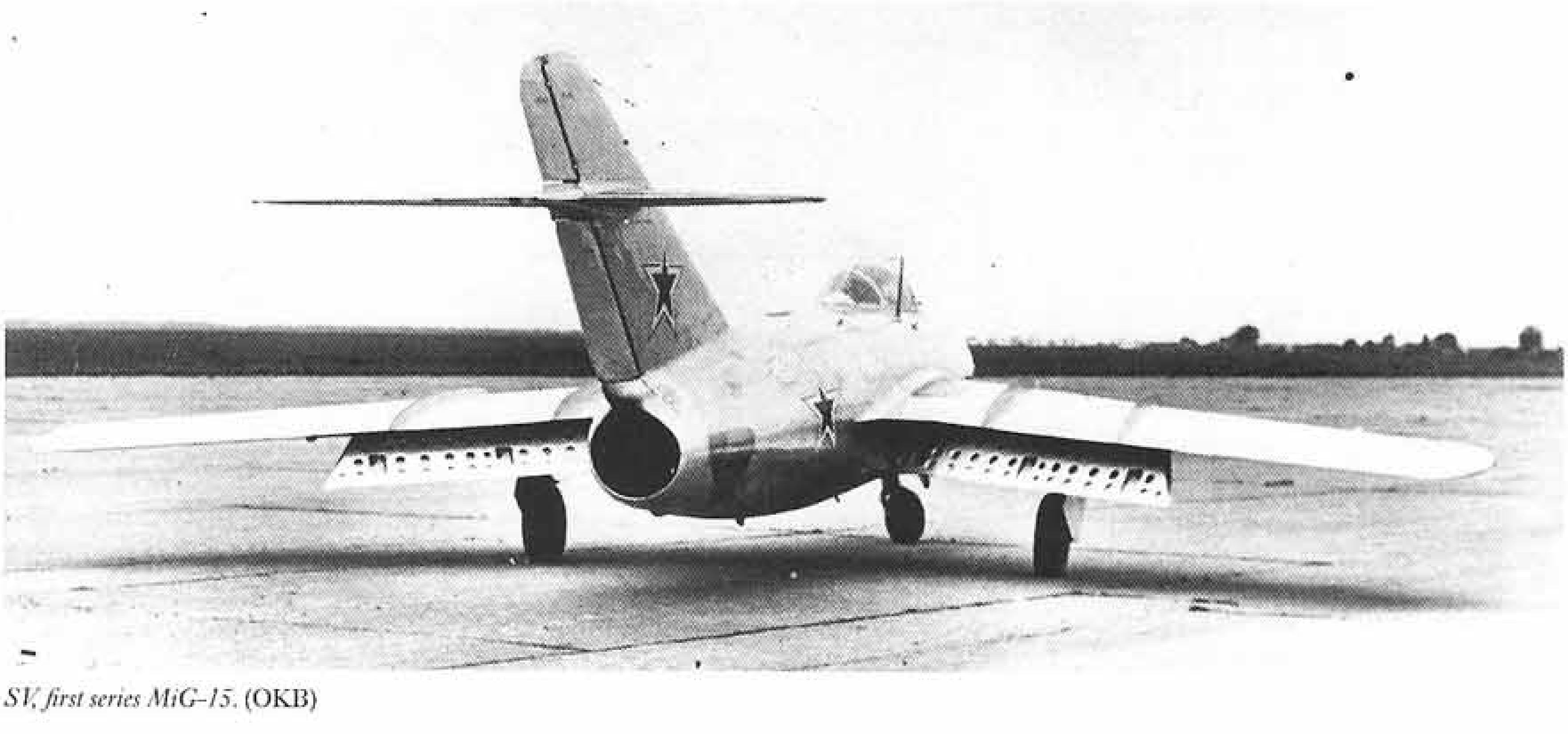
The arrangement finally adopted was to provide a trigger for the N-37D gun on the front of the stick, normally protected by a cover flap, and a thumb button to the left of the stick at the back to fire the 23mm guns. If necessary, the pilot could squeeze his hand to fire all three together. The 40 rounds of 37mm were spent in 6 seconds, and the 80 rounds per gun of 23mm in 5.3 seconds. All three guns were arranged to eject the spent cases as well as links, and the ejection chutes were enlarged and straightened to prevent jams.

During MiG-15 production the gunsight was changed to the ASP-3N. All series aircraft had wiring to control the release of two FAB-50 or two FAB-100 bombs, as an alternative to tanks; some versions carried heavier loads, as described later.

The engine starting control panel, previously on the ground electric-supply trolley, was relocated under the fuselage at Frame 13. The main battery, in the top of the nose, was changed to the lighter 12-SAM-25. The BO-39 navigation lights were replaced by brighter BANO-45 lights. Electrothermal de-icing was provided for parts of the nose, including the combat camera, and the pitot head on the starboard wing. Other items were kept ice-free by alcohol spray, and the windscreen and canopy were heated by engine bleed air.

Cockpit improvements were almost continuous. The pressurization system made it possible to fly without oxygen at altitudes up to 9,000m (29,530ft), and the cockpit was provided with both cold-air ventilation and a hot-air pipe discharging near the rudder pedals. The seat, developed at the OKB, was repeatedly modified, for example by providing a firing trigger on both armrests. The seat was fired by either summer or winter cartridges, the changeover being made at prescribed dates. As in the West, the early seats had severe limits of airspeed and safe minimum ejection altitude.

At first the usual communications radio was the RSI-6 vhf set, with a wire antenna and a long blade antenna mounted diagonally to the right of the



SV, first series MiG-15. (OKB)

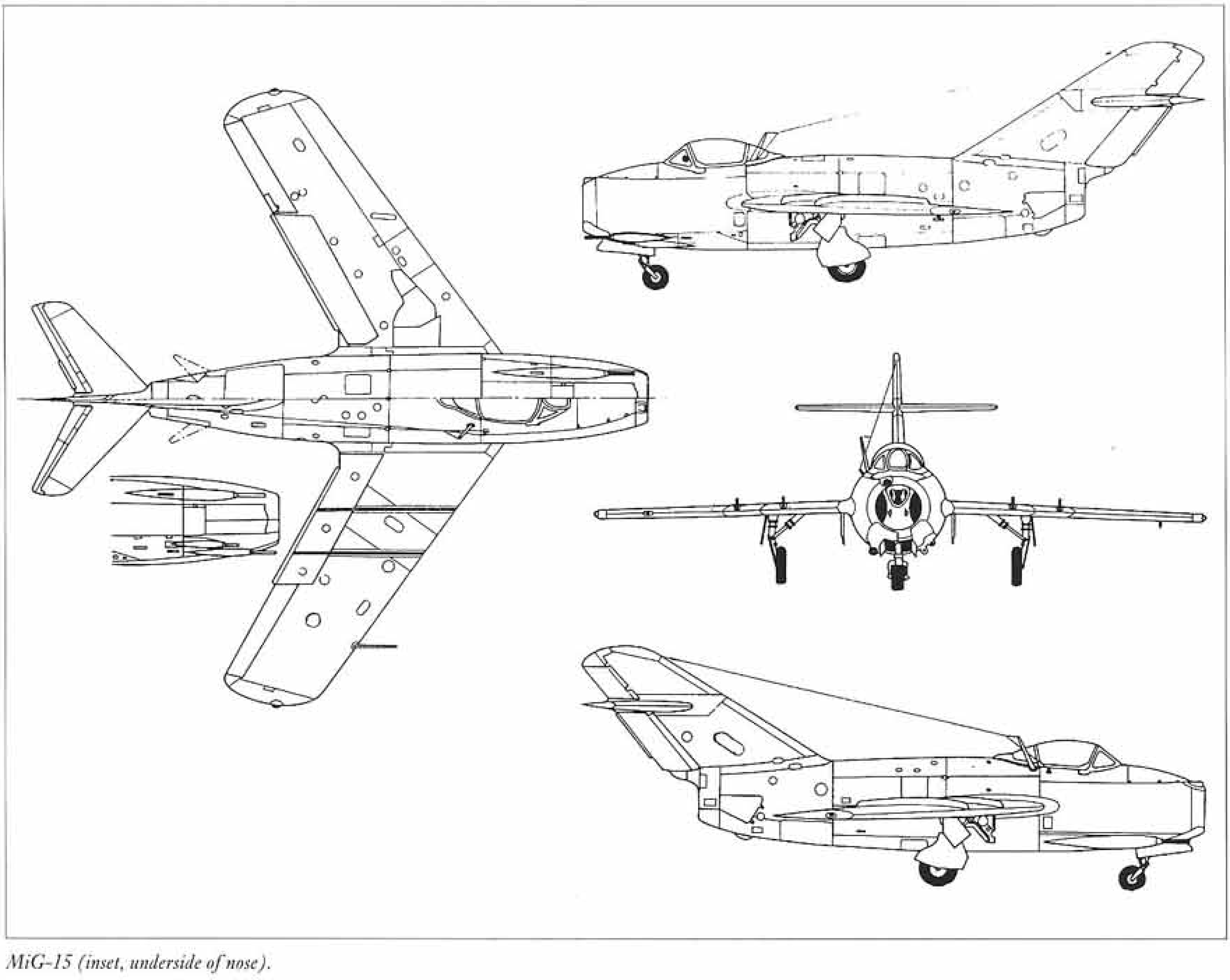
canopy. By 1950 this had been replaced by the RSI-6K. Also by 1950 the *Bariy*-M (barium) IFF (identification friend or foe) was installed, with a vertical blade antenna above the mid-fuselage. In some aircraft a raised plate antenna at the same location showed the presence of the RPKO-10M radio compass, (which was first seen on S-03), serving an ARK-5 indicator in the cockpit.

Other navaids included the PDK-45 compass in the first series, soon replaced by a KI-11 and a DGMK-3 gyromagnetic compass far out in the starboard wing, remote from interference, with a repeater indicator in the cockpit. Other instruments included the KUS-12 airspeed indicator, a Machmeter reading to 0.95, VD-17 altimeter, RV-2 radar altimeter (with two dipole antennas under the forward fuselage and either the port outer wing or the starboard wing root), the VAR-75 VSI (vertical speed indicator), and the AGK-47B horizon, which was soon replaced by the AGI-1 or AGI-51 plus the EUP-46 standby horizon.

From 1949 an increasing proportion of aircraft were fitted or retrofitted with the OSP-48 bad-weather-and-night-landing system. This comprised the ARK-5 and RV-2, linked to the MRP-48 marker receiver. Provided the pilot was skilled in their use, this combination provided guidance down to any runway equipped with the appropriate ground aids, though it was necessary to approach after flying various procedures, and the guidance was not intended to permit landing in blind conditions. OSP-48 was in any case an interim system, and (contrary to some accounts) equipped fewer than half the MiG-15 force and none of the export versions.

NII-VVS testing began on 13 June 1949. It quickly built up to involve several aircraft and many of the establishment's test pilots. The workload was enormous, partly because of the immaturity of the aircraft – the OKB was still sorting out handling, and many systems, notably the guns, were troublesome – and partly because the aircraft had not yet been cleared for night or IFR flying, spinning or any combat manoeuvres or aerobatics! The effort to overcome the problems, and also train pilots and ground crews, has been described with the words 'frantic' and 'feverish', because it was universally believed that the new MiG was potentially the best fighter in the world.

NII-VVS testing was completed on 7 January 1950, and deliveries to front-line regiments began in the same month. By this time about one hundred aircraft had been delivered and all four plants were in production. To meet the training need the biggest group of instructor pilots ever assembled was organized, because almost all the front-line pilots not only had to convert to the new fighter but also had to learn instrument flying from scratch. (To assist the task a dual UTI MiG-15 was quickly designed in 1949 and entered service from autumn 1950, as described later.)



MiG-15 (inset, underside of nose).

By sheer chance the first VVS regiment equipped with the MiG-15 was certified as combat-ready in the same month, June 1950, in which North Korea invaded South Korea, precipitating a major war. By this time the first five or six production series had settled down in service, with the flight restrictions progressively being removed, and the MiG-15 had established a reputation for basic simplicity and toughness, earning the name *samolyot soldat*, (soldier aeroplane).

The following data differ slightly from those of both the OKB and Shavrov and are those recorded on NII-VVS tests.

Dimensions unchanged.

Weight empty (typical) 3,523kg (7,767lb); fuel 1,225kg (2,701lb); oil 40kg (88lb); weight loaded (normal) 4,963kg (10,941lb); maximum with external fuel 5,405kg (11,916lb).

Maximum speed 1,050km/h (652mph) at sea level, 1,031km/h (641mph) at 5,000m (16,404ft); maximum rate of climb 42m/s (8,269ft/min); climb (clean) to 5,000m 2.3min, to 10,000m (32,808ft) 5.9min; climb (maximum weight) to 5,000m (16,404ft) 3.5min, to 10,000m 10.5min; service ceiling 15,200m (49,870ft); turn radius at 1,000m at 4,840kg (10,670lb) 460m (1,509ft); range at 12,000m (39,370ft) (clean) 1,175km (730 miles), (with two 248lit, 54.55gal tanks) 1,668km (1,036 miles); endurance (clean) 1hr 57min, (two tanks) 2hr 45min); takeoff run at 4,800kg (10,582lb) 600m (1,969ft); landing speed/run at 3,800kg (8,377lb) 168km/h (104mph)/710m (2,329ft).

As previously noted, the USAF invented a 'type number' scheme for Soviet aircraft, even when their true designation was known, and thus the MiG-15 became 'Type 14'. In 1953 this scheme was overtaken by the NATO (ASCC) system of reporting names. The name given to the MiG-15 was 'Falcon', but it was soon realized that this would do nothing for the morale of pilots who might meet this fighter in combat and it was accordingly changed to 'Fagot'.

In a remarkable new policy, the Council of Ministers decided in 1950 that certain important new weapons, including the MiG-15, should be manufactured under licence in countries under Soviet control in Eastern Europe. Why this is remarkable is that, until the signing of the Warsaw Pact on 14 May 1955, these countries were not bound militarily to the USSR. Production of the MiG-15 in Czechoslovakia and Poland is described later, but this is an appropriate point at which to insert a table of overall MiG-15 production, and a list of user air forces.

MiG-15 production

All versions in the USSR (exc. prototypes and experimental)	11,073
Czechoslovak S-102	853
Czechoslovak S-103	620
Czechoslovak CS-102	2,012
Polish Lim-1	227
Polish Lim-2	500
Chinese FT-2	800+
Total	16,085+

MiG-15 users

In the following list '15' means MiG-15, etc.

Afghanistan, 15bis, UTI; Albania, 15 (F-2 via China), FT-2; Algeria, 15, 15bis, UTI; Angola, UTI; Bulgaria, 15, 15bis, UTI; Cambodia, 15bis (F-2 via China), FT-2; China, 15 and 15bis (both called F-2), UTI, FT-2; Cuba, 15, 15bis, UTI; Czechoslovakia, 15, S-102, S-103, CS-102; Egypt, 15, 15bis, UTI, FT-2; Finland, UTI; the German Democratic Republic, 15bis, UTI; Guinea, UTI; Guinea-Bissau, UTI; Hungary, 15, S-103, CS-102; Indonesia, 15, 15bis, UTI; Iraq, 15bis, UTI; Khmer, 15, UTI; Libya, UTI; Malagasy, UTI; Mali, UTI; Mongolia, 15, UTI; Morocco, UTI; Mozambique, UTI; Nigeria, UTI; North Korea, 15, 15bis, UTI; North Vietnam, 15, 15bis (F-2 via China), UTI; North Yemen, UTI, CS-102; Pakistan, 15bis (F-2 via China), FT-2; Poland, 15, Lim-1, Lim-2, UTI and conversions; Romania, 15, 15bis, UTI; Somalia, 15bis, UTI; South Yemen, UTI; Sri Lanka, UTI; Sudan, UTI; Syria, S-103, CS-102; Tanzania, 15bis (F-2 via China); Uganda, UTI; Upper Volta, UTI.

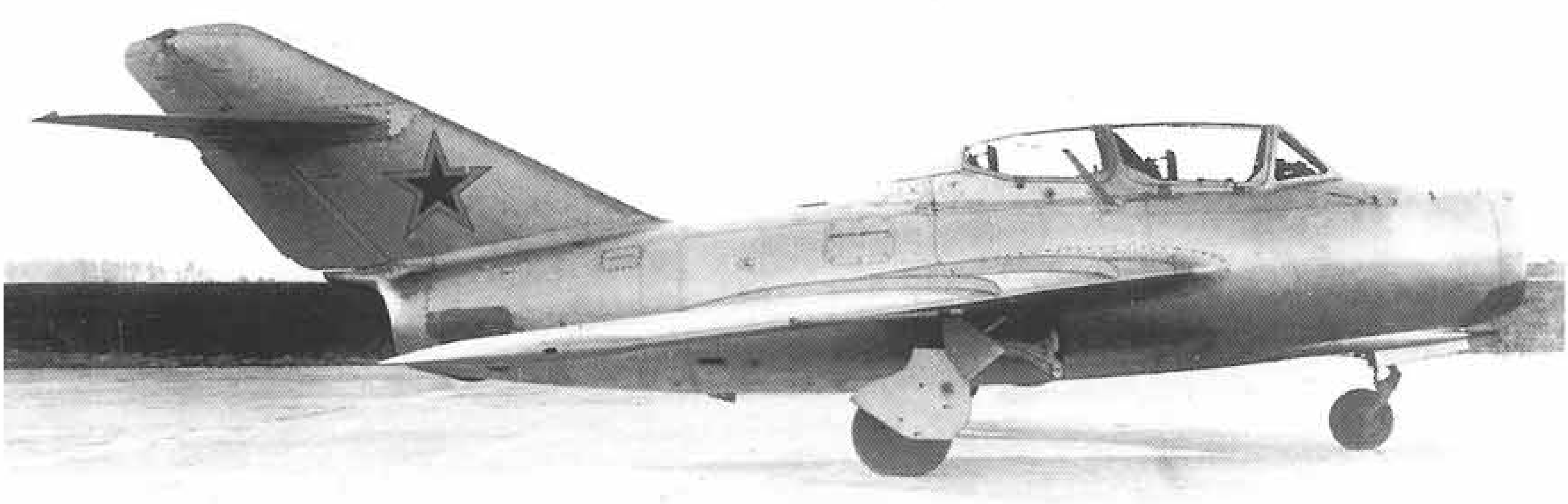
UTI MiG-15, ST, I-312

The need for a dual-control MiG-15 had been recognized as early as 1947. Not only was the MiG-15 a near-sonic swept-wing aircraft but it was expected to fly at night and in adverse weather, and hardly any VVS fighter pilots had instrument ratings. However, it was not until 6 April 1949 that the Council of Ministers signed the decree ordering a trainer version to be built. The OKB was given the instruction on 13 April in a letter from Minister Khrunichev, which stipulated that the UTI MiG-15 had to be designed and built in one month, by 15 May!

There was thus every reason to change as little as possible, beyond the obvious need to provide a rear cockpit for the instructor. The trainer prototype, with OKB designation ST-1, was thus converted from a series MiG-15 with RD-45F engine. Differences were largely confined to the cockpits and fuel system. The front cockpit retained its instruments, controls and ASP-1N optical sight. The instructor cockpit was almost identical, though of course no sight was installed. Both seats were of the same SK type as fitted to the single-seater, retaining armoured headrests, the instructor's being mounted about 250mm (10in) higher. SPU-2M intercom was fitted.

Both cockpits were pressurized and fitted with hot and cold air supplies. The canopy was entirely new. The windscreen did not incorporate a thick bulletproof slab, and was sloped at 40° instead of 55°, making it taller. Between the cockpits Frame 9 was extended upwards to form a strong arch, but without intercockpit glazing. The pupil's canopy was hinged to the right and held open by a stay pivoted above the windscreen. The instructor's canopy slid to the rear, riding on a raised platform which matched the greater height of the seat. Apart from this platform there was no fixed rear fairing.

The front cockpit was equipped with an opaque curtain system for instruction in instrument flight. Both cockpits had identical flight controls as well as landing gear and flap selectors, but if necessary – for example, to avoid imminent danger – the instructor could disconnect those in the front cockpit. In series UTI aircraft, if the instructor centralized his control column, the pupil could then reactivate his controls. For emergency escape the instructor could jettison both canopies manually or initiate an automatic cycle. The latter fired both canopies by cartridges and then ejected the instructor, closely followed by the pupil.



ST-1, prototype UTI MiG-15. (Yefim Gordon archive)

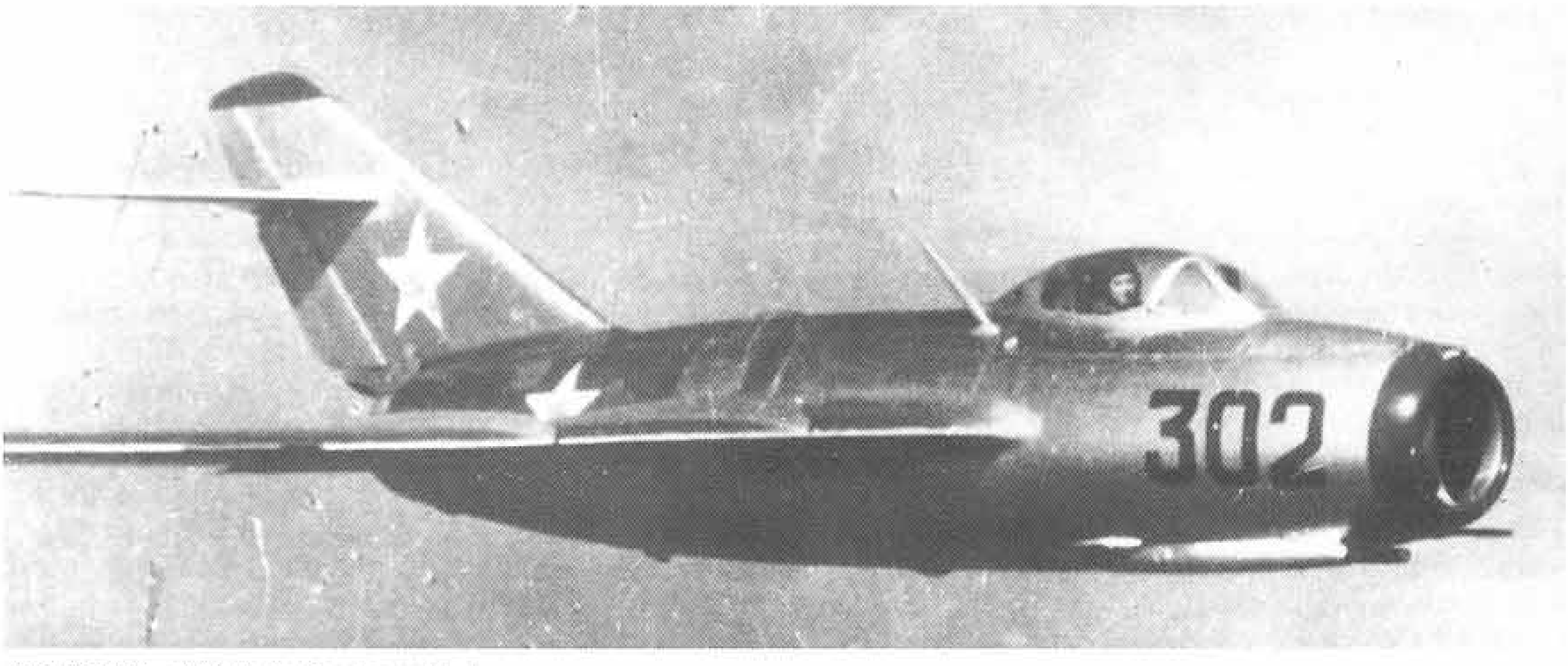
Having two-seat MiG-15s greatly assisted in developing the SK ejection seat, as described later. At entry of the MiG-15 to service in 1950 it quickly became apparent that at that time the seat was not only unreliable but also prone to cause injury when fired. This made pilots extremely unwilling to use it, even in serious situations.

Inevitably, internal fuel capacity in the two-seater was reduced. The arrangement fitted to ST-1 was never subsequently altered except in the radar-training versions. It comprised Tank 1 of 95 litres (20.9gal) under the front cockpit (in space previously occupied by equipment and gun magazines), Tank 2 of 760 litres (167gal) between Frames 9 and 13, and an enlarged rear tank of 268 litres (59gal) between Frames 21 and 24. The total of 1,123 litres (247gal) represented a loss of only 287 litres (63gal), and in any case every two-seater could be fitted with two 250 or 300lit underwing tanks.

As on the MiG-15, the tanks could be replaced by two FAB-50 or FAB-100 bombs, and at many schools dive-bombing was part of the conversion syllabus. Gunnery training was always included, and the ST-1 prototype was fitted with the removable gun tray. On it were mounted an NR-23 on the right side, with 80 rounds, and a 12.7mm UBK-E on the left, with 150 rounds. Curiously, although the UTI was not intended as a combat aircraft, a slab of armour was bolted on Frame 4 to protect the armament and a second slab above it to protect the crew against head-on attack!

ST-1 was fitted with all the usual early series MiG-15 equipment, including RSI-6 radio, RPK-10M radio compass and the S-13 combat camera, and in addition it was fitted with an AFA-1M wide-angle reconnaissance camera, because a further requirement was training in tactical reconnaissance. A standard extra was a launcher for red, green, yellow and white flare cartridges, selected and fired from the front cockpit.

A series aircraft from Kuibyshev was converted at the OKB prototype factory to produce the ST-1, which was completed on 19 May 1949. From 23 May to 20 August it made thirty-three factory test flights in the hands of Konstantin K Kokkinaki, Ivan T Ivashchenko and A N Chernoburov. Between 27 August and 25 September it completed NII-VVS trials in fifty-eight flights, few criticisms being voiced and series production being authorized soon afterwards. As with some earlier types, for service trials it was sent in October to the fighter regi-



MiG-15 '302' at LII. (Yefim Gordon archive) ment at Kubinka, being flown there 502 times until in April 1950 it was returned to the OKB for maintenance and to have the few faults rectified.

The ST-1 then made eight further factory tests by Chernoburov, and completed production testing in the hands of Sultan Amet-Khan of the LII-MAP in August 1950, being redesignated ST-2. It was the pattern aircraft for the series UTI MiG-15, which was by far the most numerous single type of MiG-15. Approximately 8,000 were built, including 2,012 Czechoslovak-built aircraft designated CS-102, but not including a large number built under licence in China as the JJ-2.

In the course of production the sight was replaced by the ASP-3N and finally by the ASP-3NM, the RSI-6 was replaced by (or augmented by) the RSIU-3 uhf, the SPU-2M intercom controller was fitted in the rear cockpit only, and some aircraft were fitted with the *Bariy*-M SRO-1 IFF transponder. Following tests with ST-2 the NR-23 cannon was replaced by the OSP-48 navigation and landing aid, and this was made standard from aircraft 10444 of the sixth series. This left the UBK-E as the only gun, and from September 1953 this was replaced by the new A-12.7 with very similar performance.

Like its Western counterpart, the Lockheed T-33, the UTI MiG-15 proved to be a thoroughly useful aircraft with a very long life. No corresponding trainer version was built of the MiG-17 or MiG-19 (except in China), and it was not until large numbers of pilots needed to convert to the MiG-21 that these popular aircraft began to be transferred to DOSAAF, or to be used for weather reconnaissance or as regimental hacks (until 1968 every fighter regiment had at least four). One UTI was used for cosmonaut training, specializing in zero-g trajectories. Many others were special testbeds, some being described later.

The UTI MiG-15 and Chinese-built JJ-2 served with at least thirty-six air forces, some aircraft remaining serviceable into the 1990s. To its pilots it was the *Sparka* (twin). To the USAF in 1951 it was 'Type 29', a reporting code later replaced by the ASCC name 'Midget'. As with the MiG-15, the data below are typical, because with so many aircraft from several factories, there were variations.

Dimensions unchanged.

Weight empty 3,724kg (8,210lb); fuel 900kg (1,984lb); oil 35kg (77lb); weight loaded 4,850kg (10,692lb); maximum weight with 300lit tanks 5,400kg (11,905lb).

Maximum speed limited at sea level to 900km/h (559mph), rising to 1,015km/h (631mph) at 3,000m (9,843ft), thereafter falling to 950km/h (590mph) at 13,000m (42,650ft); Mach limit 0.894; climb to 3,000m (9,843ft) 1.6min, to 5,000m (16,404ft) 3.2min, to 10,000m (32,808ft) 7.8min; service ceiling 14,625m (47,982ft); range at 10,000m (clean) 950km (590 miles), or with 300lit tanks 1,500km (932 miles); takeoff run 570m (1,870ft); landing speed 172km/h (107mph); landing run 740m (2,428ft).

MiG-15 variants

Very approximately, of the more than 11,000 MiG-15s built in the USSR, about 5,000 were single-seaters. The only versions built in large series were the MiG-15, UTI MiG-15 and MiG-15bis, but there were numerous prototype and experimental versions.

SA-3

Under this designation fifteen production aircraft were fitted with the OSP-48 bad-weather-and-night-landing system. To make room for the MRP-48 marker receiver and ARK-15 radio compass the No. 2 fuel tank was replaced by two cells of reduced capacity, the AFA-1M camera was removed and the instrument panel was rearranged. The SA-3 batch were returned to service as OSP-48 trainers, assisting the later general introduction of this equipment throughout many MiG-15 regiments.

SA-4

This was a single MiG-15, which was equipped not only with OSP-48 but also with many other upgrades. These included an air-data sensor calibrated up to Mach 0.95, triggered to extend the airbrakes automatically at this speed, a further improved panel with a KI-11 compass system, DGMK-2 gyrocompass, AGK-47B attitude indicator and an audio/visual general failure-warning indicator, a hydraulic/pneumatic landing-gear control valve and an engine inflight-starting system. The SA-4 completed factory testing in August 1950, and was then transferred to the NII-VVS. The upgrades became standard on the MiG-15bis.

SO

This MiG-15, with NR-23 guns, was used to test enhanced pilot protection. The seat backrest and headrest were enlarged, and the windscreen was made thicker. To reduce injuries in crash landings the ASP-3N sight was arranged automatically to retract into a stowed position under violent deceleration. Flight testing was completed in early 1950, following which the SO was transferred to the LII-MAP for prolonged diving trials to Mach numbers above 0.92.

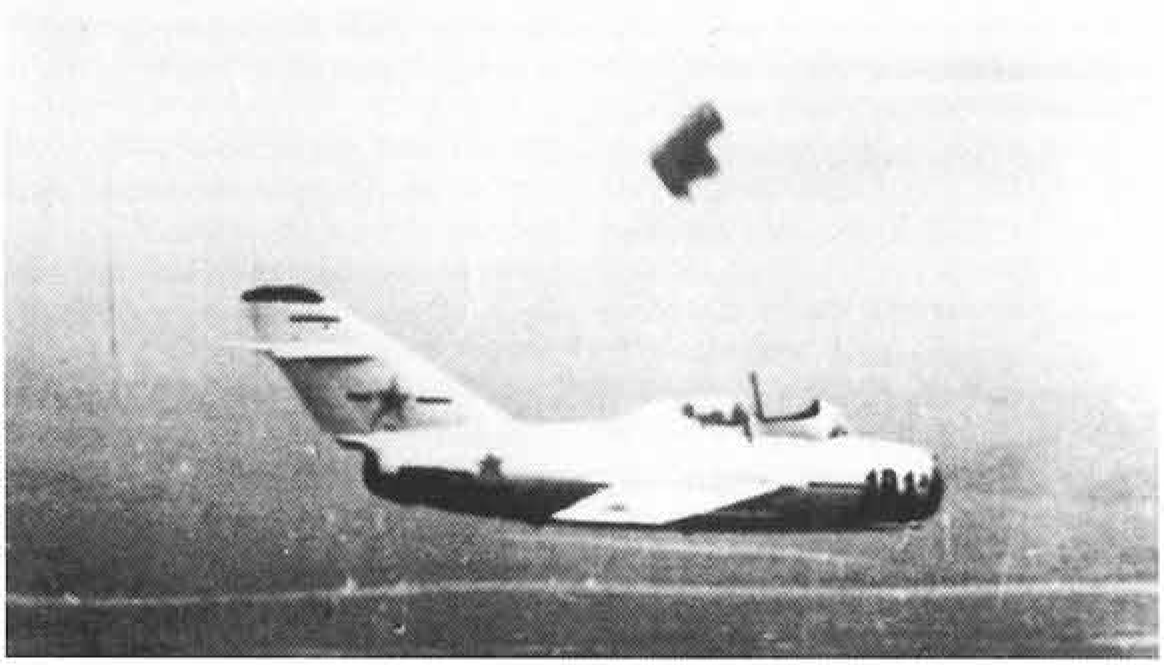
SSh

This designation identified two aircraft built at Kuibyshev which in 1950 were modified with the two left guns replaced by a single 23mm Sh-3. The high-power Shpital'nyi gun required complete redesign of the mounting, magazines and fuselage fairings. The second aircraft was submitted for NII-VVS test on 1 July 1950, and the first followed on 13 July. Test results were unsatisfactory.

SU

The Sh-3 gun was also used in this aircraft, which incorporated a variable-angle installation on which the OKB had worked from 1949. The Shpital'nyi bureau designated the installation V-I-25-Sh-3. The complete system, which replaced all the original armament, comprised two Sh-3 guns mounted on trunnions and capable of being elevated to +11° and depressed to –7° (there was no lateral movement). The irreversible electric screw-jack drives were slaved to a modified sight and controlled by switches on both the pilot's stick and throttle. The guns and magazines were not mounted on a removable tray, and each gun had its own deep faired blister. A single aircraft (No. 109035, callsign '935', *see* overleaf) was converted under a Ministry order of 14 September 1950, and factory testing took place between 2 January and 27 March 1951. NII-VVS testing followed from 30 June to 10 August 1951. The general opinion was that the scheme 'improved the MiG-15's tactical performance'. It proved useful in tight dogfight turns and, particularly, in making head-on attacks without risk of collision. The recommendation called for an improved sight and for the ability to aim over a much greater vertical arc. This led to the SV MiG-17.

'Red 935' SU. (OKB)



'101U' UTI MiG-15LL seat test, usually from the rear cockpit. (RART/GP)

UTI MiG-15P, ST-7

The ST-7 was a single UTI MiG-15 which in winter 1951–52 was converted to serve as a trainer to teach pilots to use the RP-1 *Izumrud* (Emerald) interception radar. Developed by the KB of V V Tikhomirov, this radar had previously been tested in a MiG-15bis (described later, *see* SP-5). As far as possible the ST-7 installation and cockpit duplicated that of the single-seater. Armament comprised a single UBK-E. Testing proved satisfactory, and a small number were delivered to combat units with the designation UTI MiG-15P.

ST-8

Despite its earlier designation, this testbed followed the first ST-10s. Built as a UTI MiG-15, it was rebuilt in 1955 as the flying testbed for the improved *Izumrud* RP-3 radar. Much of the forward fuselage was new, the No. 1 fuel tank was removed to make room for the radar power supply and other equipment, and the nosewheel unit was strengthened.

UTI MiG-15LL, ST-10

Many UTI MiG-15s were converted into flying testbeds for ejection seats. callsigns included '15', '23', '101U', '102U' and '401U'. Most were painted with bold horizontal black lines to assist cine and theodolite recording. Several designs of SK seat were tested, fired from either the front cockpit or (usually) the rear, and many hundreds of combinations of canopy, ejection gun, parachute system and stabilization were investigated, using dummies and human occupants. Three ST-10s did extensive testing with no canopy at all over the test seat, while '401U' was used to develop a canopy over the front cockpit which was hinged at the rear to the top of the seat to protect the occupant from windblast. This arrangement later went into production for the MiG-21.

Specifications for all the modified MiG-15s differed only in very minor ways from those for the series MiG-15 or UTI MiG-15.

MiG-15bis, SD

The French-derived word 'bis' meant second version, and was common in Soviet aircraft programmes. The MiG-15bis was externally almost indistinguishable from the MiG-15, but incorporated numerous improvements tested previously in many MiG-15s, as well as some which were new, the most important of these being a more powerful engine.

As soon as he had an actual Rolls-Royce Nene Vladimir Klimov began working on ways of increasing its power. Thus, while preparations were made for mass-production of the RD-45F, he quickly produced prototypes of an engine he considered he could justifiably call the VK-1. The key feature was an enlarged compressor, handling a mass flow increased from 40 to 48.2kg/sec, resulting in an increase in thrust from 2,270 to 2,700kg (5,952lb). The penalty was an increase in weight from 808 to 872kg (1,922lb), and slight increases in overall dimensions. Diameter was increased from 1,255 to 1,273mm (50.1in), and this required the MiG designers to make minor changes to Frames 21 to 28.

The VK-1 made a significant improvement to the already good flight performance. This was backed up by various airframe and flight-control modifications. Minor changes were made to strengthen the wing and its root attachments. The B-7 aileron booster was replaced by a BU-1, the greater power enabling aileron chord to be increased to 21 per cent. During MiG-15bis production the aileron circuit was again upgraded, with a BU-1 reversible booster ahead of the main spar in the starboard wing. The aerodynamic balance of the elevators and rudders was improved by redesign of their leading edges, and the elevator inset hinges were extended to increase mass balance to 22 per cent. Airbrake operation was improved by using a solenoid valve controlled by a stick button, and the brakes were again reshaped to eliminate pitch-up. The jetpipe was enlarged, and the tail end of the fuselage modified (*see* drawings overleaf).

Systems changes were numerous. The cockpit pressurization was improved, and a hot-air pipe could be turned on at the front of the cockpit. Engine oil was passed through a screen-type filter. The signal-flare launcher was controlled by a new panel indicating the number and colour of each flare available. Armament was unchanged: some early bis fighters retained the NS-23KM but all built after July 1951 had the NR-23, the sight remaining the ASP-3N. Not only did the new gun have a much faster firing rate but the mountings were improved to reduce dispersion.

All the above improvements were incorporated in the SD prototype, which underwent factory testing from 2 July to 9 September 1949. NII-VVS testing followed, and the improved fighter was recommended for production. This took some time to organize in view of the very high rate of MiG-15 production. Originally called MiG-15 with VK-1, the new fighter was designated MiG-15bis in 1951, soon after deliveries began.

Improvements naturally began at once. Concerned at the landing distance required (even without snow and ice a typical figure was 2,887ft, 880m) three types of braking parachute were tested from 20 May to 20 July 1951. These were the TP-1453-50 of 7.2sq m (77.5sq ft), the TP-20 of 20.4sq m (220sq ft) and a twin TP-1453-50 installation. None was satisfactory, but the UA-11 antiskid braking system worked well and was adopted. From 4 to 20 September 1951 a fourth parachute, the PT-2161-51 (PT, not TP), of 15sq m (161.5sq ft), performed adequately. In 1952 Kuibyshev built a batch of aircraft with this parachute and antiskid system, and these entered service.

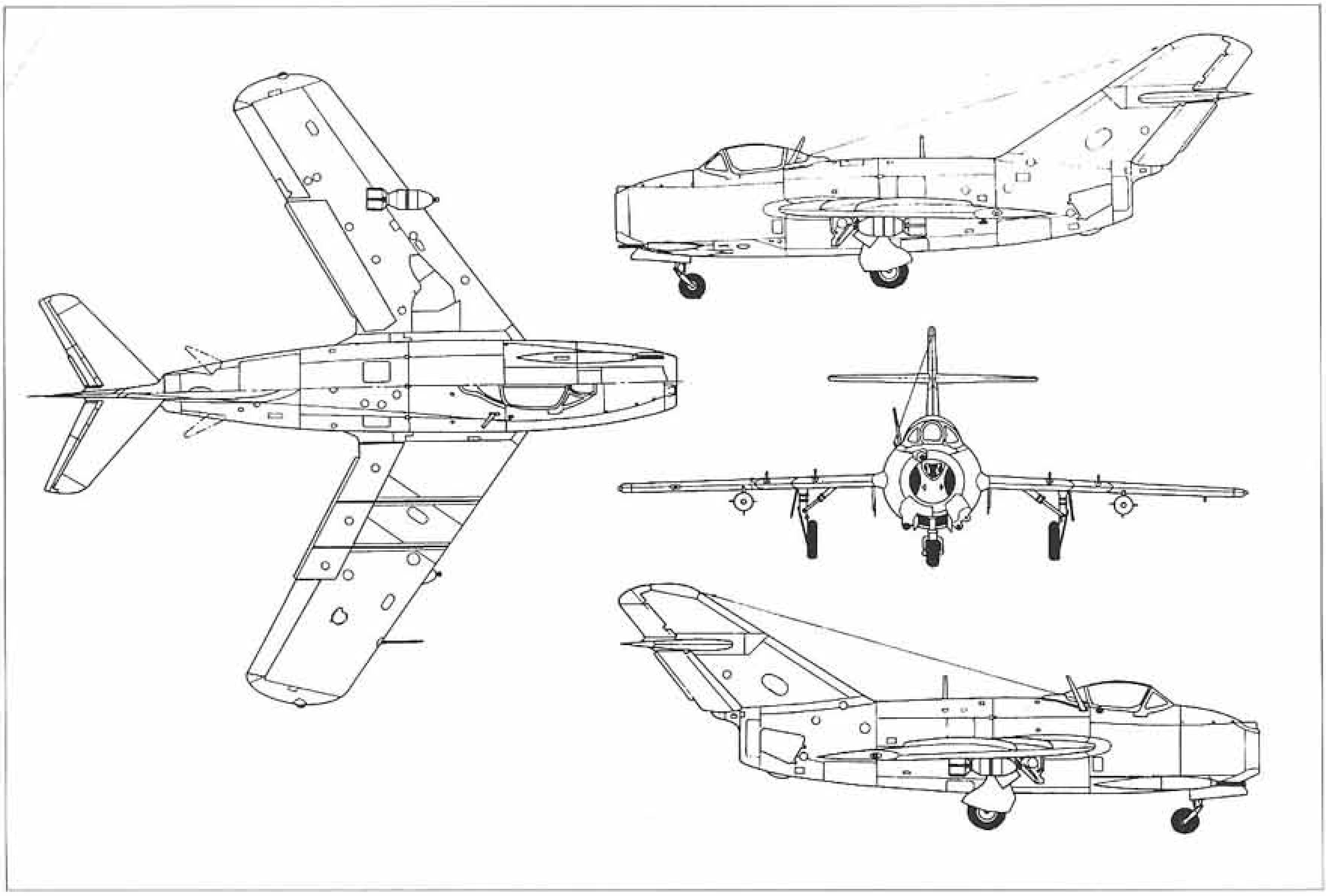
Another 1951 programme was aimed at improving rearward vision. The fixed rear canopy, 10mm (0.394in) thick, was improved optically and mounted in a narrow steel frame. This entered production in 1952. In June 1952 the S Vavilov Optical Institute supplied a TS-23 rear-view periscope, tested on one aircraft, and a TS-25 for a second. The TS-23 gave an inverted image, while the TS-25 lacked demist/defrost capability. Vavilov later developed the TS-27A, used on the MiG-17.

Previously developed, the PPK-1 g-suit system was fitted to series aircraft from early 1952. It used filtered bleed air from the engine to inflate the chambers of the suit depending on the g-loads experienced. The system g-limits were +1.75 to +8.0. Another 1952 modification was to increase the size of the airbrakes yet again, improving the ability to make steep dives at high altitude.

The MiG-15bis was the most numerous single-seat variant. It was built under licence in Czechoslovakia and Poland (totals given previously) and used by thirty-six air forces, as well as the Soviet VVS, Frontal Aviation, PVO and Naval Aviation. From November 1950 it saw intensive combat against the USAF and US Navy/Marines over North Korea and China, flown by experienced Russians and totally inexperienced Chinese.

Its principal opponent was the F-86 Sabre (A, E and F versions). At the time the USAF claimed a kill:loss ratio better than 14 : 1 for this aircraft, but it is now known that the actual figure was nearer to 3.5 : 1. This reflected the enormous difference in pilot capa-

MiG-15bis with 250lit tanks. (OKB)



MiG-15bis.

bility, and the two fighters were actually quite well matched. In particular, the MiG-15bis had far more devastating armament. According to the top-scoring Russian, Evgeny Pepelyaev, who shot down nineteen US fighters confirmed, 'the fifty-calibre bullets rattled on the MiG like peas. Our aircraft would return with 40 to 50 bullet holes. The MiG-15, and especially its engine, could take damage far better than the Sabre'. The ASCC name remained 'Fagot', without a suffix.

Dimensions unchanged.

Weight empty (with OSP-48) 3,681kg (8,115lb); internal fuel 1,173kg (2,586lb); weight loaded (clean) 5,044–5,055kg (11,120–11,144lb); maximum (with two 600lit tanks) 6,106kg (13,461lb).

Maximum speed 1,076km/h (669mph) at sea level, 1,107km/h (688mph) at 3,000m (9,842ft), 1,014km/h (630mph) at 5,000m (16,404ft); maximum rate of climb (clean) 46m/s (9,055ft/min); climb to 5,000m 1.95min, to 10,000m (32,808ft) 4.9min; service ceiling 15,500m (50,850ft); range (clean, at 12,000m/39,370ft) 1,330km (826 miles) with endurance 2hr 6min, (two 600lit tanks) 2,520km (1,566 miles) with endurance 3hr 52min; takeoff run (clean) 475m (1,558ft), (maximum weight) 600m (1,970ft); landing speed 178km/h (111mph); landing run 670–880m (2,198–2,887ft).

MiG-15bis variants

All *Sparka* trainers were based on the MiG-15, but many derivatives and experimental versions were based on the MiG-15bis.

SA-1

This aircraft was retrofitted with the OSP-48, in the installation developed on the MiG-15 (SA-3). Other features included RSIU-3 vhf replacing the RSI-6 hf, *Bariy*-L IFF and improved cockpit heating/cooling. To restrict weight growth the AFA-1M camera, SOPT differential-pressure indicator, VS-46 altitude switch, gun rounds counter and Frame-5a armour were all removed. Following factory testing in February–March 1950, VVS testing recommended OSP-48 for production.

SI

This considerable modification was in effect the prototype MiG-17, as described later.

SD-ET

This prototype gathered together a long list of improvements. To stop wing drop at high Mach numbers the wing stiffness was again increased. Hydraulic system pressure was reduced, to avoid problems which had arisen. To avoid damage to the rear fuselage in hard landings the nose leg was made 'softer'. To stop sudden movement of the throttle lever on the VK-1 an ART-8 acceleration control was interposed. To stop engine overspeeding a PN-2FAK fuel-flow restrictor was inserted. To ensure steady engine idling a DK-6K minimum-fuel-pressure limiter was added. The ST2-48 starter was fitted, independent of ground power. A GF-1103 chemical filter was fitted in the air bleed pipe serving the cockpit. The NR-23 back plates were strengthened, holding the guns more firmly. The drop tanks were given individual jettison switches. Following factory and NII-VVS testing in 1950 nearly all these modifications were accepted.

MiG-15Sbis, SD-UPB

This version was developed as an escort for the Il-28 and Tu-14 jet bombers. The only available fighter for this task was the La-11, which was piston-engined. The SD-UPB prototype had 'underwing tanks of 1,170lit' (257gal). This, which was clearly the combined capacity of both tanks, required BD2-48 pylons with D4-48 tank shackles. Factory testing took place from 10 June to 21 July 1950, using welded AMTs light-alloy tanks. Testing continued with three further tank designs, the final version being a 600lit (132gal) conformal type with a narrowed top scabbed against the wing. Factory testing was completed on 19 September 1950, resulting in the SD-UPB escort fighter, factory tested in November. In January 1951 this aircraft passed NII-VVS testing, resulting in limited production of the MiG-15Sbis escort fighter. Figures for weight, range and endurance were given in the MiG-15bis data.

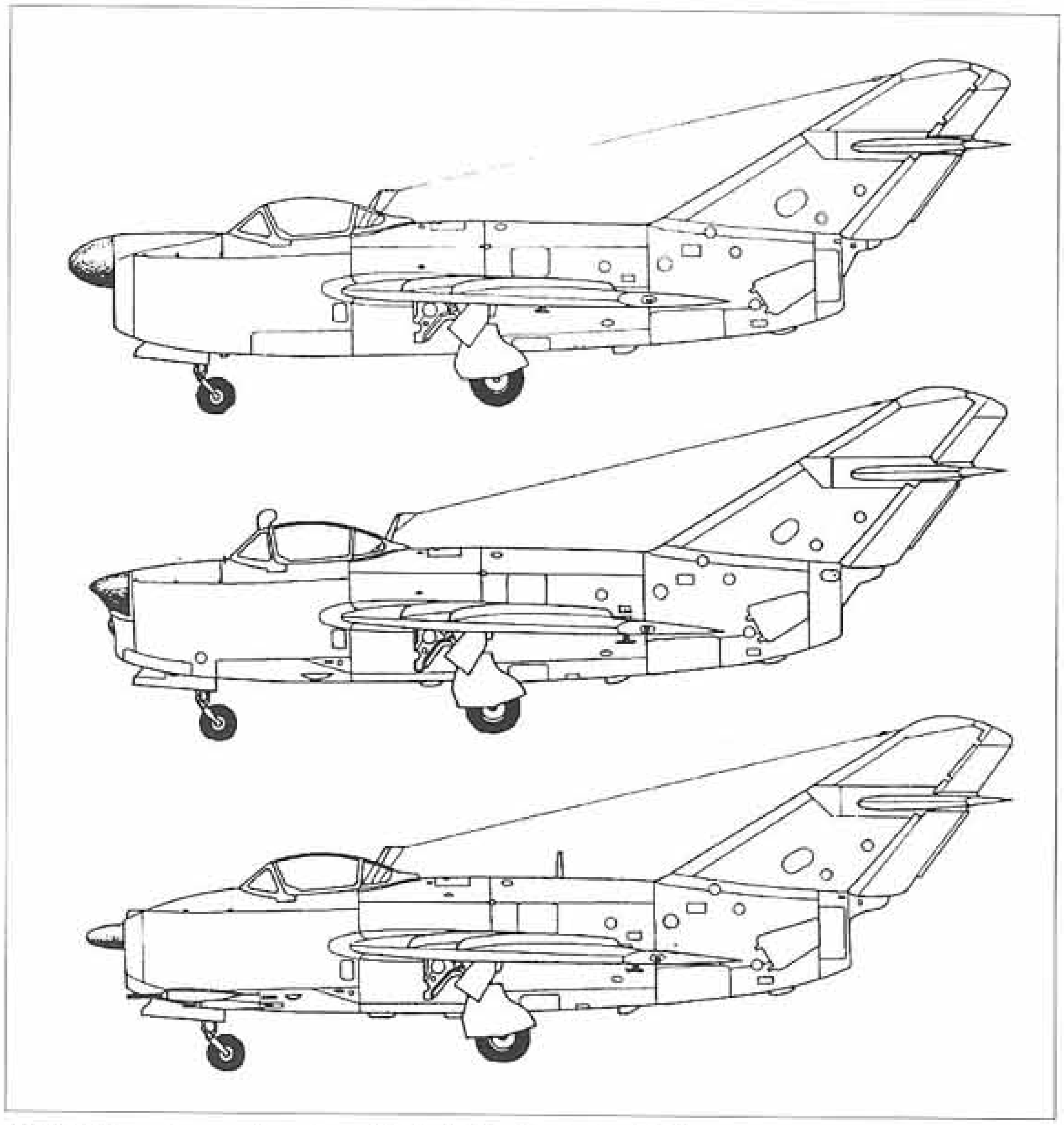
After these aircraft were in service the capacity of the oxygen bottles was increased from 6 litres to 8 litres. A further modification, which was made standard, was the use of expanding-tube brakes.

MiG-15Rbis, SR

The SR prototype (also often called SR-1) was the first MiG-15 for the dedicated reconnaissance mission. The AFA-1M camera had never been satisfactory, and the SR was an SA-1 aircraft, equipped with OSP-48, in which was fitted an AFA-BA/40 camera of 40mm focal length. It was mounted vertically under the cockpit. It required the removal of the inboard NR-23, and was controlled from a cockpit command panel. The other two guns and the S-13 gun camera remained. Improvements were also made to cockpit pressurization. Following much refinement, the SR underwent successful NII-VVS testing, ending on 10 July 1951. The resulting MiG-15Rbis, or MiG-15bisR, was built in fair numbers, with both the NR-23 guns and the camera faired in a large ventral box. These aircraft served for many years, fitted with various sizes of drop tanks.

SP-1

The biggest of all the MiG-15 development programmes was aimed at solving the urgent problem of equipping high-performance interceptors with radar, to counter the growing threat of jet bombers with nuclear weapons.



MiG-15bis versions: reading down: SP-1; SP-5; Czechoslovak SB.

On 7 December 1948 the Council of Ministers issued a decree calling for rapid development of radar for jet interceptors. Three design teams immediately began work, and the Mikoyan team chose the *Toriy* (thorium), developed by the OKB of A B Slepushkin. Also called RP-2 and 2U, and much later dubbed 'Scan Can' by NATO, this centimetric set had search, track and gun-ranging facilities, using a single parabolic dish antenna. This made it easier to accommodate than rival twin-antenna radars, though tracking put a heavy workload on the pilot (Mikoyan also developed a bigger twin-engined, two-seater with *Toriy*-M radar, *see* I-320).

The SP prototype had the radar in place of the two 23mm guns, leaving as sole armament the N-37D with 45 rounds. Its mechanically scanned antenna was mounted at the top of the nose in a bullet radome, the S-13 camera moving to the right side. Airflow to the engine was unaffected. According to some accounts the jetpipe was enlarged, the wing incidence increased and the aerodynamic balance of the tail control surfaces increased.

The SP was put through factory testing by Sedov and Chernoburov

MiG-15bis, SP-1. (OKB)

between 23 April 1949 and 20 January 1950. NII-VVS testing was completed on 20 May 1950, during which the inboard fences were made thicker, to increase wing torsional stiffness and eliminate the endemic problem of wing dropping at high Mach numbers. Further testing took place in August 1950, following which, in 1951, Mikoyan converted five MiG-15bis with the improved *Toriy*-M radar. One of these began NII-VVS testing on 25 November 1951. The aircraft was flown by many test pilots, who intercepted Tu-4 and Il-28 bombers.

It was concluded that, with this radar, ordinary front-line pilots would find it too difficult to make interceptions. Mikoyan told Slepushkin he would wait until automatic interception radars were available for single-seaters, and meanwhile switched to the *Izumrud* series (already mentioned, *see* SP-7).

MiG-15bisP, SP-5

Though the *Izumrud* radar has already been mentioned in the section on UTI MiG-15 versions, by far the most important testbed was this single-seater. Developed by the design bureau of V Tikhomirov, RP-1 *Izumrud* (Emerald), later called 'Scan Odd' by NATO, was developed from late 1948. Unlike *Toriy*, it used two antennas, one for searching for targets and the other for locked-on target tracking, gun aiming and ranging. A centimetric set with 50–60 kW transmitter power, it could scan ±60° in azimuth and from +26° to –14° in elevation, each sweep taking 1.33 seconds. Maximum range for typical targets was 12km (7.45 miles).

With the radar warmed up, the pilot looked through the ASP-3N gunsight, where a target was indicated as a short line, the length depending on target size and range. Once the fighter had closed to within 2km (1.2 miles) of the target, which had to be inside a 7° cone directly ahead, the pilot could switch to the tracking mode. The sight's computer then indicated direction within 1° and range within 150m (492ft), and also indicated horizon marks to give the pilot an attitude indication.

The SP-5 was the first of numerous MiG aircraft with different *Izumrud* radars, with the search antenna in the upper lip of the intake and the tracking dish in a small radome centred inside the inlet, mounted on the splitter. The S-13 camera was on the right of the nose, and a second S-13 was mounted in a prominent fairing above the windscreen looking down through the ASP-3N sight reticle. Armament comprised just two NR-23 cannon, one on the left of the nosewheel bay with 120 rounds and one on the right with 90. The SP-5 was fitted with the old RSI-6 hf radio and a simplified OSP-48.

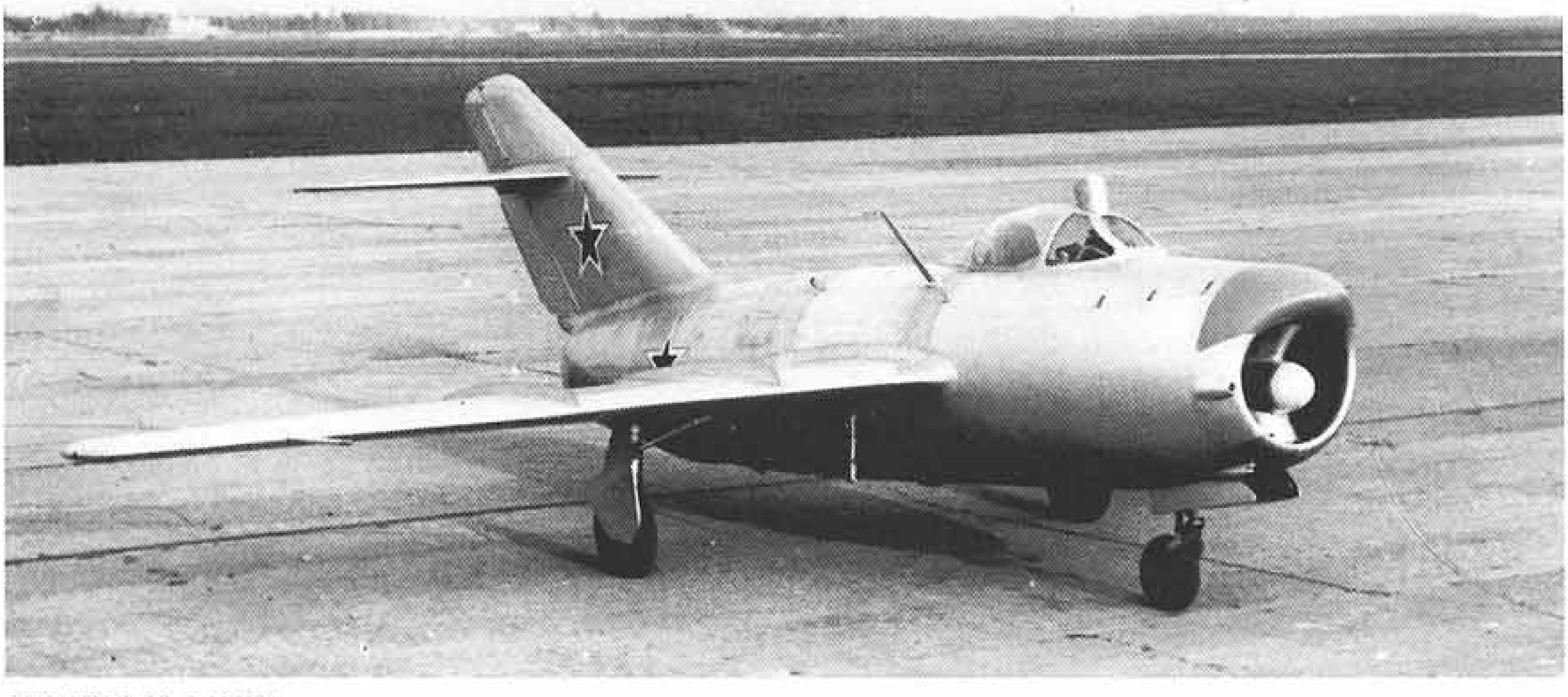
This aircraft was factory tested from 22 August to 9 September 1950. With functioning radar it then underwent further testing until 30 July 1951. It then went to the NII-VVS where State testing proved generally successful. As a result, RP-1 *Izumrud* went into service in 1952 on the MiG-17P and MiG-17PF, and also led to the RP-2 and RP-5 used in the MiG-17PFU and MiG-19PM armed with missiles.

SL-5

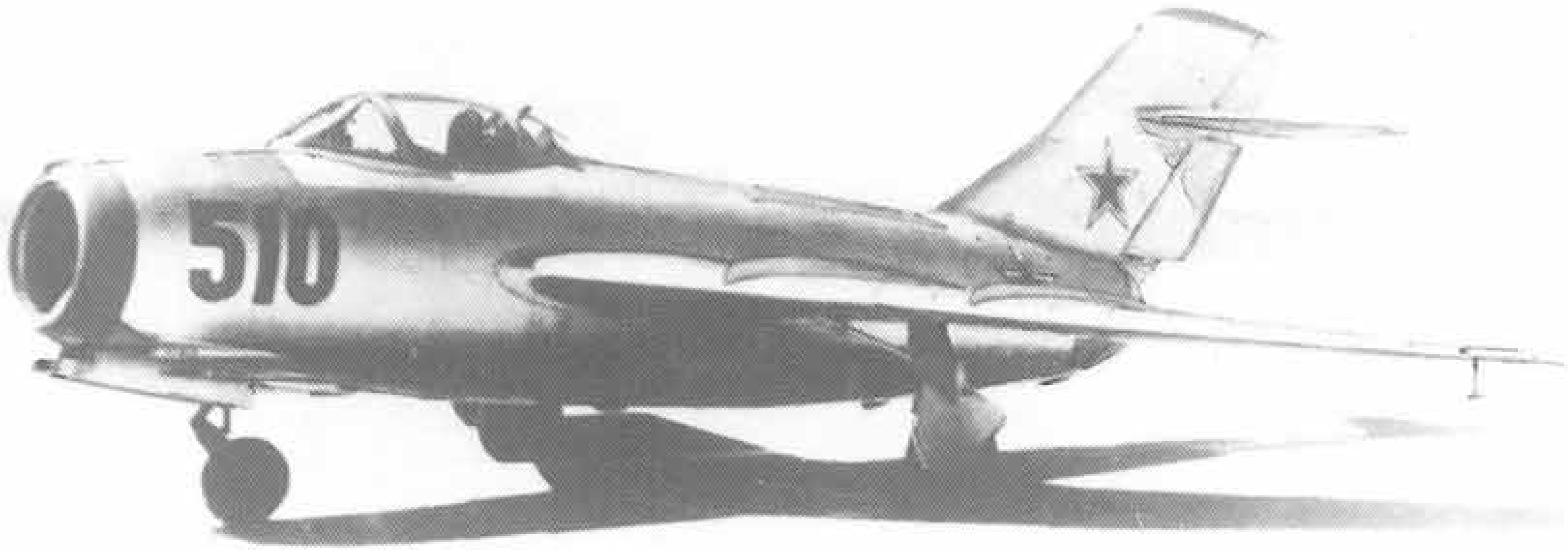
This MiG-15bis was the main flying testbed for Klimov's VK-5 engine, in which further increases in mass flow, plus other changes, raised thrust to 3,000kg (6,614lb). Airframe modifications included revised engine mounting trunnion pick-ups and a redesigned tail end to the fuselage. Assisted by CIAM, factory testing took place from 15 August to 31 October 1951, but the engine was abandoned in favour of axial types.

MiG-15LL, SYe

The endemic problem of poor or reversed lateral control, wing drop and inadequate yaw control at high Mach numbers was studied over a long period by the CAHI aerodynamicists. Another team worked at the LII-MAP, two of whose workers, I M Pashkovskiy and D I Mazurskiy, made recommendations to Mikoyan, as a result of which two research aircraft were built called SYe. The most obvious change was the huge vertical tail, engineered by V P Yatsenko (designer of the I-28 fighter of 1938, who joined MiG in 1941). The wings were again stiffened above the landing-gear bays, and fitted with square-tip ailerons of increased span but slightly reduced chord.



MiG-15bisP, SP-5. (OKB)



MiG-15LL, SYe. (Yefim Gordon archive)

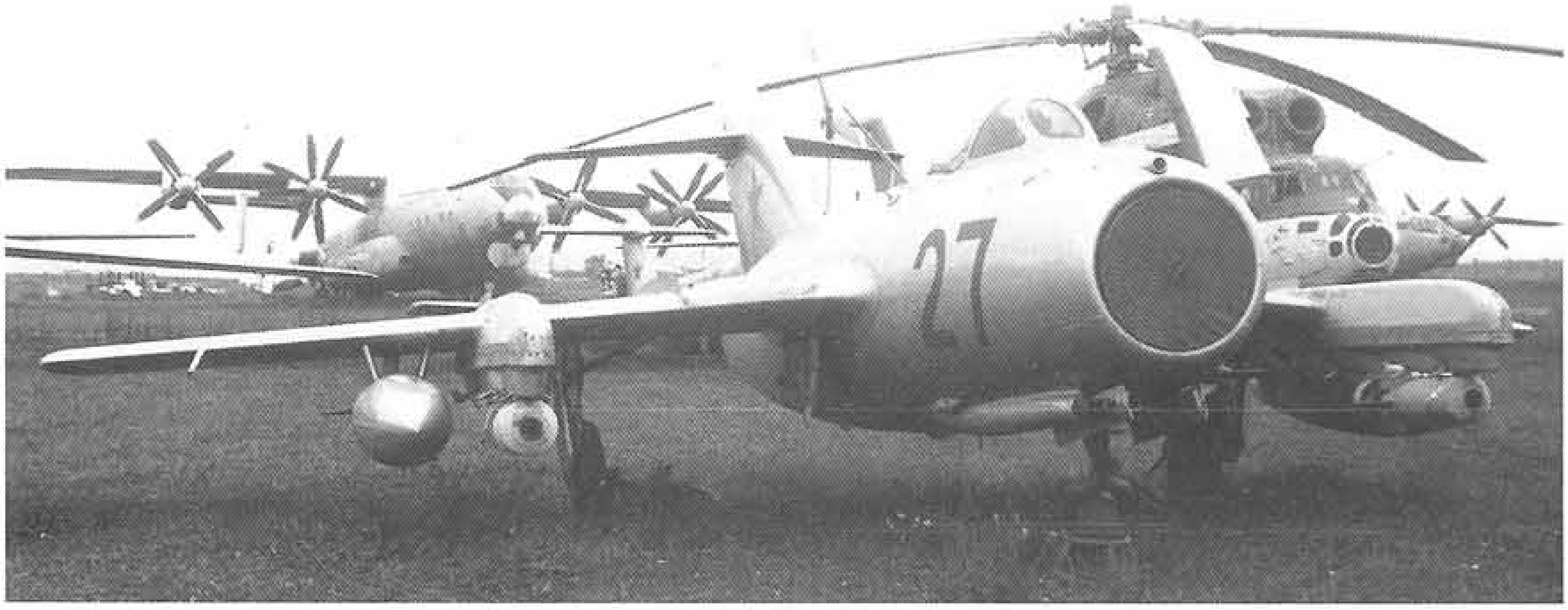
The first SYe, callsign '510', was tested at the LII-MAP. At first it had unboosted ailerons but, despite this, on 21 September 1949 D M Tyuteryev dived from 12,000m (39,370ft) to reach Mach 0.985. After the aircraft had been fitted with BU-1 aileron boosters Tyuteryev dived beyond Mach 1 on 18 October 1949 (the La-176 had done so nearly a year earlier).

MiG-15bis, SD-57. (OKB)

SD-21, SD-57, SD-25

A number of SD armament test aircraft were used to assist development of rockets and dropped stores. The SD-21, callsign '407', retained its 300lit drop tanks, but immediately inboard were fitted D3-40 pylons with an APU-0-212 interface for an ARS-212 rocket.

MiG-15bis, SD-21. (OKB)



MiG-15bis, ISh. (photograph by Yuriy Popov)

Three S-13 cameras were installed, one behind each pylon and one above the nose. Also called S-21, the 212mm (8.35in) calibre rockets were later issued to Frontal fighter/bomber regiments.

The SD-57 was a MiG-15bis, which in June 1952 began testing the 57mm (2¼in) rocket. These were fired from twelve-tube ORO-57 launchers hung on D4-50 pylons. This rocket was later made by the million. In November 1950 the SD-5 was used to test the same type of launcher on the D3-40 pylon, with an integral AKS-2 camera.

The SD-25 was fitted with D4-50 pylons interfaced with PROSAB-250 bomb containers. These were designed to scatter bomblets over formations of hostile aircraft (or other targets). Later the smaller PROSAB-100 went into service on MiG-15bis regiments in the PVO.

ISh

The designation *Istrebitel' Shturmovik* literally meant 'fighter, armoured attacker', though the MiG-15bis armour was unchanged. The wings were reinforced, and inboard of the drop tanks were hung long beam-type pylons with interfaces for tandem bombs (typically FAB-100 or OFAB-100) or NURS launchers for various heavy rockets. One report states that the aircraft preserved at Monino, call-sign 27, was the only ISh built; but another states that twelve were built.

Burlaki

This was one of the schemes suggested in order to escort Tu-4 bombers on strategic missions. Invented and engineered by the OKB of A S Yakovlev for the Yak-25E, it involved the bomber reeling out a cable with a crossbar on the end. The fighter pilot closed from astern and caught the crossbar on a sprung harpoon clamp above the nose. He then froze for hours whilst being towed with the engine shut down. The idea was that, if enemy fighters were encountered, the MiG-15 pilot would start the engine, disconnect and engage battle. He then had to find the Tu-4 again and hook on. The scheme was not pursued, and the problem was solved by the Tu-16 and Tu-95, which were not considered to need an escort. *Burlaki* is Russian for a barge-hauler.

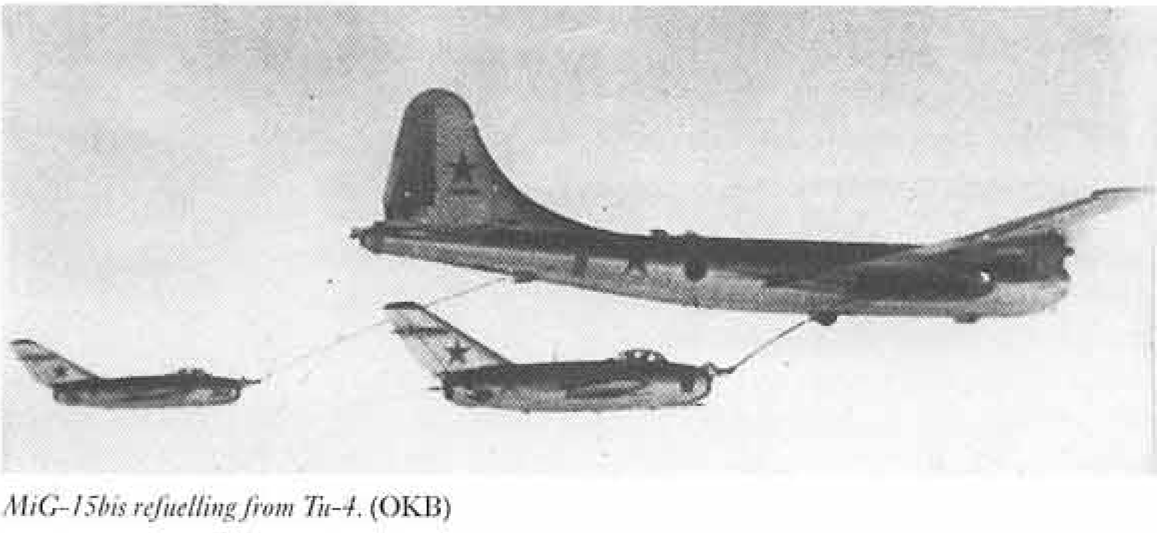
Air refuelling

This was investigated as an alternative method of escorting long-range bombers. Again Yakovlev was important, though Vakhmistrov and test pilots Shelest and Vasyanin also contributed. Like the method devised by the British firm Flight Refuelling, the first scheme involved one pipe fired across another. Next came a unique method which linked the wingtips of the tanker and receiver. Finally, again like Flight Refuelling, the answer was a probe thrust into a trailed drogue. Many successful hook-ups and fuel transfers were made using bomb-bay hose-drum units on a Tu-4 tanker, with the hoses carried through the wings to emerge from fairings on the wingtips. Two MiG-15bis could receive simultaneously.

Problems included the need for a suitable homing beacon to enable the receiver to find the tanker in bad weather, probe breakages caused by oscillating hoses, the need for more rapid transfer, and the fact that on breaking contact a lot of fuel entered the fighter's inlet. The VK-1 was tolerant of this, but the dense fuel vapour contaminated the air fed to the cockpit.

SDK-5, SDK-7

Following their withdrawal from front-line service, numerous MiG-15s and MiG-15bis were converted as pilotless drones. Some were used to



MiG-15bis refuelling from Tu-4. (OKB)

develop the technology, some had a preprogrammed autopilot and others were remotely piloted via a radio link. The SDK-5 was a radio-controlled target version which was used alongside the specially developed La-17 for firing practice by PVO regiments with both guns and missiles. The SDK-7 was a preprogrammed cruise-missile version for use against large ground targets. These pilotless conversions also assisted the MiG OKB and others to develop control systems for later cruise missiles.

Foreign MiG-15s

Czechoslovak

In 1950 the Kremlin took the bold decision to allow Soviet weapons to be produced under licence in neighbouring so-called 'satellite' countries. One of the first of these licence agreements concerned the MiG-15 and its engine. Originally the aircraft was assigned to the Rudý Letov factory at Prague-Letnany, with the designation S-102, while the RD-45F engine was put into production at Motorlet (the former Walter factory) at Prague-Jinonice, with the designation M-05.

S-102

Parts for several fighters were sent by train, and these were assembled by Letov in 1952, using Soviet engines. However, later in 1952 production was switched to the Aero factory at Vodochody, and here the first Czechoslovak-built S-102 made its first flight on 28 April 1953. Over the next two years Aero built 853 S-102 fighters, which Soviet test pilots considered indistinguishable from Soviet production.

S-103

In 1954 production switched to the MiG-15bis, with the designation S-103. Motorlet's VK-1 engines were designated M-06. They powered Czechoslovak MiG-15bis and Il-28 aircraft, and by the late 1950s Motorlet closed this engine production line with just over 5,000 engines delivered. Aero built 620 S-103 fighters in 1954–56, some being exported to Egypt and Syria.

CS-102

In 1956 the Aero plant replaced the S-103 by the licence-built UTI MiG-15, with the designation CS-102. Very soon the entire production of the UTI version was entrusted to Czechoslovakia and Poland. The Aero factory delivered 2,012, most of which were exported to almost every air force flying the MiG-15, MiG-17 or MiG-19, the largest number going to the Soviet Union. It was widely considered that they were finished to a higher standard than the Soviet-built UTI MiG-15. At an early stage many S-103 and CS-102 aircraft were retrofitted with the Czechoslovak PPZ-1 bad-weather-and-night-landing system (based loosely on the OSP-48), which required a prominent pointed radome above the nose housing the receiver antenna.

MiG-15bisF

Also dubbed *Photobis*, these were S-103s in which the gun pack was replaced by AFA-1M or AFP-21KT reconnaissance cameras.

MiG-15bisR

Also known as the MiG-15Rbis, these were more extensively modified. The left NR-23 gun was retained, the rest of the under-cockpit area being devoted to an AFP-21KT and two additional reconnaissance cameras. For night photography, one of the cameras was an NFT-02. To accommodate these cameras the capacity of No. 1 fuel tank was reduced, so drop tanks were invariably carried.

MiG-15SB

From 1958 many S-102s were modified for the fighter/bomber mission, the wings being fitted with six pylons. The middle pylon on each wing was plumbed for a tank, usually of 400 litres (88gal). The other four pylons commonly carried single R-130 (130mm) rockets, SR-55 (55mm) rocket launchers or OFAB-100M fragmentation bombs. The guns were retained, so fully loaded this version weighed 6,270kg (13,823lb). Except on long runways two SRP-1 rockets were clipped on the rear fuselage to shorten takeoff, and a braking parachute was installed.

MiG-15bisSB

Possibly the last new front-line modification, this dated from 1968. Based on the S-103, this added the six pylons of the MiG-15SB, but the greater power of the M-06 engine was a factor in the decision not to fit assisted take-off rockets or a parabrake. A single MiG-15bisSB was tested for the air force of North Vietnam with K-13 AAMs and an IR target detector in place of the N-37 gun.

UTI MiG-15P

This aircraft was a single CS-102 modified as a radar trainer. It looked almost identical to the Soviet ST-8, but in fact the rebuild was considerable because the inlet was that of a MiG-17PF and the forward fuselage was that of a MiG-19S. The radar was the later RP-5 (*Izumrud*-5), as fitted to the interceptor versions of the MiG-17. The radar controls and display were in the rear cockpit, and internal fuel was reduced by 7.7 per cent. This aircraft is preserved at the Prague-Kbély museum.

MiG-15T

Under this designation several S-102s were converted with a windmill-powered winch and cable system for service as target tugs. The MiG-15bisT was the corresponding conversion of the S-103. Usually the guns were removed from these aircraft.

Not designated

Without receiving new designations, several CS-102s were modified for ejection-seat testing. The last of these, registered OK-10, was used for all the testing on the seat for the L-39 trainer, including ejections on the runway.

Polish

In 1951 the decision was taken to manufacture the MiG-15 and its engine under licence in Poland. The aircraft was assigned to the WSK factory at Mielec, and given the designation Lim-1 (*licencyjny myśliwiec*). The RD-45F engine was put into production at the WSK factory at Rzeszów, and given the designation Lis-1 (*licencyjny silnik*).

Lim-1

The first Lim-1 (No. 1A-001) was assembled from Soviet parts and flight tested by Maj Eugeniusz Pniewski on 17 July 1952. The Lim-1 was in production at Mielec until 1 September 1954, 227 being built in 12 blocks. They did not differ in any significant respect from the MiG-15. Many were later retrofitted with OSP-48, *Bariy*-M IFF and a landing light and designated Lim-1.5.

Lim-2

In late 1953 production began to switch to the MiG-15bis, which received the designation Lim-2, the VK-1 (not VK-1A) engine becoming the Lis-2. The first Lim-2 (No. 1B-001) was completed on 17 September 1954. The 500th and last (No. 1B-019-14, meaning the fourteenth aircraft of the nineteenth production block) came off the assembly line on 11 November 1956. Lim-2s of later blocks, delivered in 1956, were fitted with OSP-48, the *Bariy*-M IFF and a landing light hinged down from the port wing. None of the Polish-built fighters were exported.

Lim-2R

A substantial number of Lim-2s were delivered equipped for the day reconnaissance mission. An AFA-21 camera was installed under the cockpit behind the NR-23 guns, projecting slightly in a square box under the fuselage.

SB Lim-1

In the late 1950s the need of the PWL (Polish Air Force) for jet trainers was so acute (as it was throughout the Warsaw Pact) that it could not be met from Soviet and Czechoslovak production. Accordingly the Mielec factory had to rebuild some Lim-1 fighters into trainers, using drawings from the MiG OKB. The engine was the Lis-1. Designated SB (*szkolno-bojovy*), they closely followed the UTI MiG-15, but had a single NS-23 with 80 rounds.

SB Lim-2

Though every trainer made elsewhere retained the original RD-45 type of engine, Poland ran out of stocks of the Lis-1 in 1973, and a year later decided to convert some Lim-2 fighters into trainers, retaining the more powerful Lis-2 engine. These also retained one NS-23, with 80 rounds. To increase reliability and extend life the engines were downgraded to a takeoff rating of 2,400kg (5,291lb), receiving the designation Lis-2SB.

SB Lim-1Art, SB Lim-2Art

These were modifications of the two trainer versions for use as tactical reconnaissance aircraft. A special data link was provided to notify targets for ground forces. The designation came from *artyleryjskij*.

SB Lim-1A, SB Lim-2A

These were conversions of the two trainer versions for the day photographic-reconnaissance role. Usually the SB Lim-1A had two NS-23 guns, a single AFA-21 camera and 400lit drop tanks, while the SB Lim-2A had two NR-23 guns, two cameras, an AFA-21 and AFA-39, and 600lit drop tanks.

SB Lim-2R

This variant had a completely different installation of one or more short-focus reconnaissance cameras mounted obliquely in the front of the removable rear fuselage. Even though this caused a pronounced ventral canoe fairing, it is remarkable that there was room, because the engine occupied the full cross-section at this point.

SB Lim-2M

This was the last of the Polish trainer versions. All were modified SB Lim-2A aircraft, retaining two NR-23 guns. The rear cockpit for the instructor had new equipment (not specified).

Not designated

Numerous single-seat Lim fighters were modified to test new Polish equipment, some launching the SPD-3, SPD-3bis and SPD-6 heavy meteorological rockets from under the wings in almost vertical climbs. The shortage of jet trainers resulted in Polish industry designing the TS-11 Iskra, and various Lim aircraft supported this programme, in particular serving as trials aircraft for the ejection seat. A later testbed was two-seater callsign '002', above which was constructed a framework on which was mounted a full-scale mock-up of the forward fuselage, including an operative seat, for the later I-22 Iryda jet trainer!

Data for Polish MiG-15s:

Span (Lim-1, Lim-2, SB) 10.08m (33ft ⅞in); length (Lim-1, Lim-2, SB) 10.1m (33ft 1⅝in),

Weight empty (Lim-1) 3,382kg (7,456lb), (Lim-2) 3,681kg (8,115lb), (SB) 3,762kg (8,294lb), internal fuel (Lim-1) 1,460kg (3,219lb), (Lim-2) 1,412kg (3,113lb), (SB) 998kg (2,200lb), weight loaded (Lim-1) 4,806kg (10,595lb), (Lim-2) 5,044kg (11,120lb), (SB) 4,876kg (10,750lb); maximum weight (Lim-1) 5,260kg (11,596lb), (Lim-2) 5,574kg (12,288lb), (SB) 5,446kg (12,006lb).

Maximum speed (Lim-1) 1,043km/h (648mph) at 3,000m (9,843ft), 1,023km/h (636mph) at 6,000m (19,685ft), (Lim-2) 1,044km/h (649mph) at 3,000m (9,842ft), (SB) 932km/h (579mph) at 5,000m (16,404ft), 906km/h (563mph) at 10,000m (32,808ft), 889km/h (552mph) at 12,000m (39,340ft); climb to 5,000m (Lim-1) 3.5min, (Lim-2) 3.2min, (SB) 4min, climb to 10,000m, (Lim-2) 6.6min, (SB) 8.7min; service ceiling (Lim-1) 15,200m (49,870ft), (Lim-2) 15,500m (50,853ft), (SB) 13,950m (45,768ft); range (Lim-1) 1,920km (1,193 miles), (Lim-2) 1,976km (1,228 miles), (SB) 1,290km (802 miles); takeoff run (Lim-1) 600m (1,969ft), (Lim-2) 504m (1,654ft), (SB) 540m (1,772ft); landing run (Lim-1) 710m (2,329ft), (Lim-2) 880m (2,887ft), (SB not available).

Chinese

At the start of 1950, possibly forewarned by North Korea of the forthcoming invasion of South Korea, the Chinese government invited a Soviet MiG-15 regiment to Beijing. This regiment came from Kubinka in February 1950. One month later, in March 1950, the Chinese government decided to undertake the production of jet aircraft.

The Korean War started on 25 June 1950, and in early 1951 the Soviet Union began supplying China and North Korea with a few MiG-15s (but the recipient air forces had virtually no experience of such aircraft). In October 1951, 847 Soviet engineers and other MiG-15 specialists travelled to the industrial complex at Shenyang (previously called Mukden), where it was intended that the MiG-15 should be built.

The Chinese called the aircraft the J-2 (*Jianji*), and its engine the TJ-4. Plans were also drawn up for manufacture of the UTI MiG-15 as the JJ-2 (*Jianji jiaolianji*). The Chinese also allotted the designation J-4 to the MiG-15bis, and its engine became the TJ-5. During the Korean War 534 battle-damaged MiG-15 and MiG-15bis fighters were repaired at Shenyang, but in fact these aircraft were never built in China.

On the other hand, the JJ-2 did go into production, several hundred being used as the standard Chinese jet trainer until the end of the 1970s. Other Chinese-made trainers were exported to Albania, Bangladesh, North Korea, North Vietnam, Pakistan and Tanzania. The export designation was FT-2.

I-320, R-1

In January 1948 a specification was issued calling for a fighter able to carry radar and intercept hostile aircraft as far from the defended target as possible by day or night, or in any weather. This led to the establishment of the radar design bureaux of A V Slepushkin and V V Tikhomirov, while responses to the demand were made by the OKBs of MiG, Lavochkin, Sukhoi and Yakovlev. Thus, four completely different prototypes competed.

Yakovlev designed a light interceptor with a single seat and single engine. Sukhoi designed a single-seater with two engines. Lavochkin and the MiG OKB accepted that managing the radar and interpreting its display was a full-time task, and accordingly provided for a second crew-member, which in turn resulted in a bigger aircraft with two engines. Surprisingly – because the configuration was never repeated in any later aircraft – MiG, Lavochkin and Sukhoi all elected to use a nose inlet supplying air to one engine in the forward fuselage, with a jetpipe under the belly, and a second engine in the rear fuselage, with a jetpipe at the tail.

As far as possible, Aircraft R used established principles (though historian Shavrov called it 'very innovative'). Aerodynamically it resembled the MiG-15, the wing having the same aerofoil profile and sweep, the same pairs of fences and similar boosted ailerons. Differences were that the anhedral was –3° instead of –2°, the CAHI/Fowler flaps were extended on tracks parallel to the longitudinal axis to the increased angles of 22° for take-off and 56° for landing, and that roll induced by rudder deflection was countered by fitting narrow interceptors (in effect, spoilers) on the underside of the wings ahead of the ailerons. With a span of 0.9m (35.4in), these were opened electrically as soon as rudder deflection exceeded 2°.

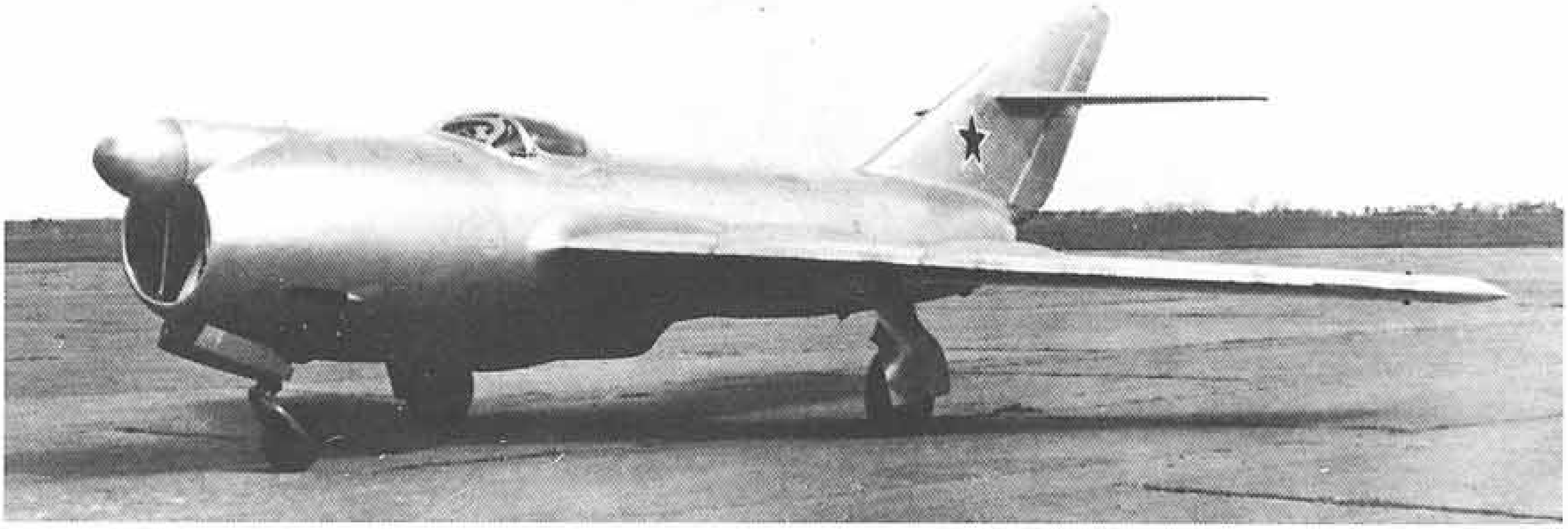
The ruling diameter of the forward fuselage was 1.9m (74.8in). Like previous MiG interceptors, the scanner for the Slepushkin *Toriy*-A (thorium) radar was to be housed in a radome at the top of the nose, though the radar was not ready for the R-1 prototype. The circular inlet was divided into three, the central duct feeding the plenum chamber housing the front RD-45F engine and the side ducts passing on each side of the cockpit to the plenum chamber for the rear RD-45F. Apart from the complex air ducts, the engine installations were reminiscent of the MiG-9 (front engine) and MiG-15 (rear).

The tail was again reminiscent of the MiG-15, but the enormous fin had a leading-edge sweep increased to 59°27′, and the relatively small tailplane had a leading-edge sweep of 40°. As before, the elevators were tabbed and had mass balances at the tips, and moved with hydraulic boost from 17° down to 33° up. The upper and lower rudders were internally balanced, the lower having a 'knife' strip on its trailing edge. The rudder limits of travel were ±24°48′. The airbrakes were larger than those of the MiG-15, each having an area of 1.08sq m (11.6sq ft), driven open to 45°.

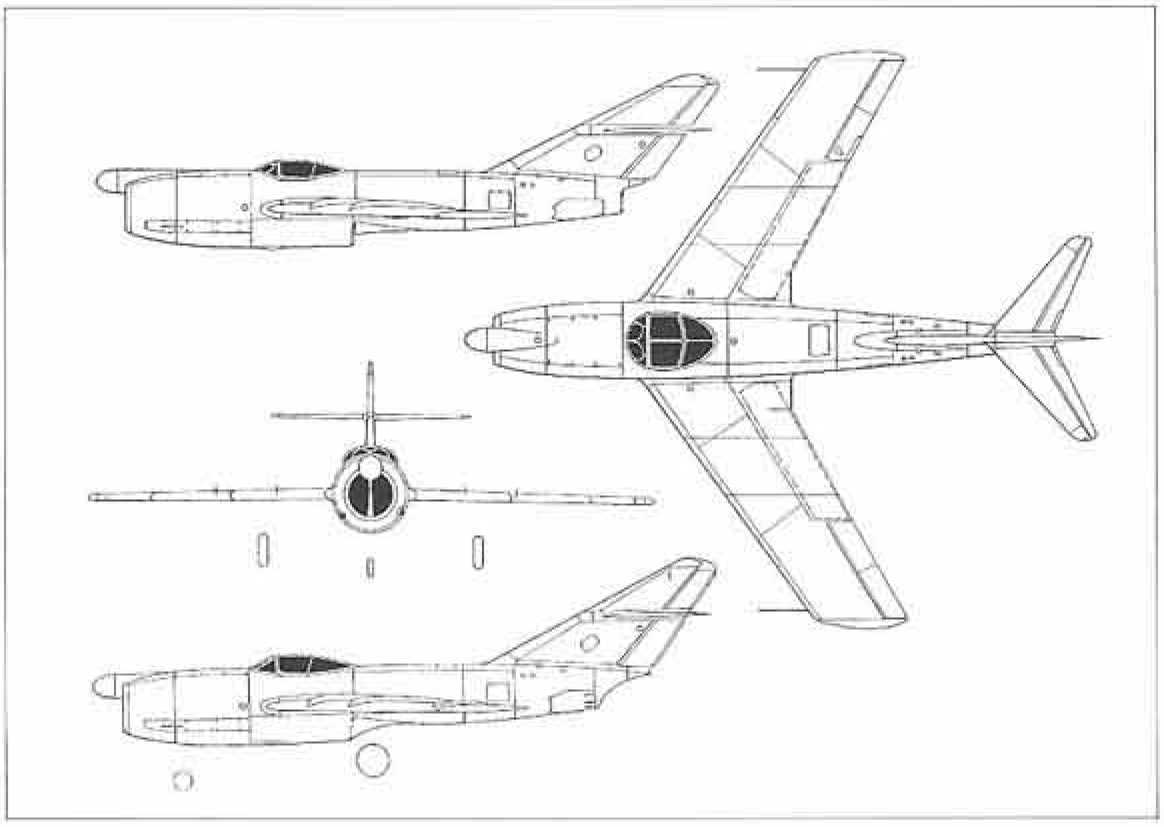
Again, the landing gear resembled a strengthened version of that of the MiG-15. The nose unit had a levered-suspension leg carrying a castoring wheel with a 520 × 240mm tyre. It retracted forwards into a narrow bay with a streamlined cover projecting into the centre duct. The main legs were pivoted at the junction of the main and transverse spars, as in the MiG-15, the track being no less than 5.444m (17ft 10¼in). Wheelbase was 4.754m (15ft 7¼in). Each unit had a levered lower arm carrying a wheel with a two-shoe drum brake and 900 × 275mm tyre. The unit retracted inwards into the wing, the bay being closed by doors on the leg and a door hinged under the wing root.

The capacious cockpit was unpressurized, and covered by a windscreen with two optically flat front windows each 105mm (4.13in) thick, and a wide aft-sliding canopy. It housed two pilot stations side by side. Each had an OKB-developed ejection seat (MiG-15 type), a complete set of instruments and a visor-type radar display, and controls for the aircraft, engines, systems, radar and armament. The left seat was intended to be occupied by the captain, and the right seat by the radar operator. The captain was to manage the mission, fly the aircraft and fire the guns, while the right-seater was to use the radar to guide the captain to targets and share the flying on long patrols.

The requirement ignored any alternative mission, and no provision was made for underwing stores apart from tanks. Armament comprised two N-37 cannon, one on each side of the forward fuselage with the muzzles well behind



I-320, R-1. (OKB)



I-320, R-1; bottom, R-2.

the inlet. Originally the magazines under the cockpit floor held 50 rounds each, but this was later increased to 60. Fire control was electrical, and the guns were cocked pneumatically.

The same compressed-air system controlled the brakes on the mainwheels, but (apart from the spoilers) all other secondary power was hydraulic. The Main and Emergency systems operated the landing-gear units and their doors, the flaps, and the boosters on the ailerons and elevators. Fuel was housed in two bladder-type cells in tandem between the cockpit and the rear engine. The front tank had a capacity of 1,670 litres (367.4gal) and the rear tank 1,630 litres (358.6gal) including a small separate section which continued to feed the engines under negative g. Thus, total capacity was 3,300 litres (726gal). The wings were designed for drop tanks, but these were not fitted to R-1.

Load factor was originally 5.9g up to a weight of 8,530kg (18,805lb), but during the design process it was increased to the same 8g value as the MiG-15. The original *Toriy*-A radar was not cleared to this loading.

The OKB built two prototypes, R-1 and R-2, and the NKAP allotted the experimental designation I-320. The R-1 was first flown on 16 April 1949, the crew comprising very experienced LII-MAP pilots Yakov I Vernikov and Sultan Amet-Khan. The aircraft handled well, the only problems being a repetition of the MiG-15 difficulties of wing drop (between 930 and 940km/h, 578–584mph) and roll instability around Mach 0.895. This prevented it from being certificated, but the R-1 was favourably received by two more very experienced pilots, Sergei N Anokhin and Mark L Gallai, as well as by Lt-Gen Ye Ya Savitskiy, Commander of the PVO.

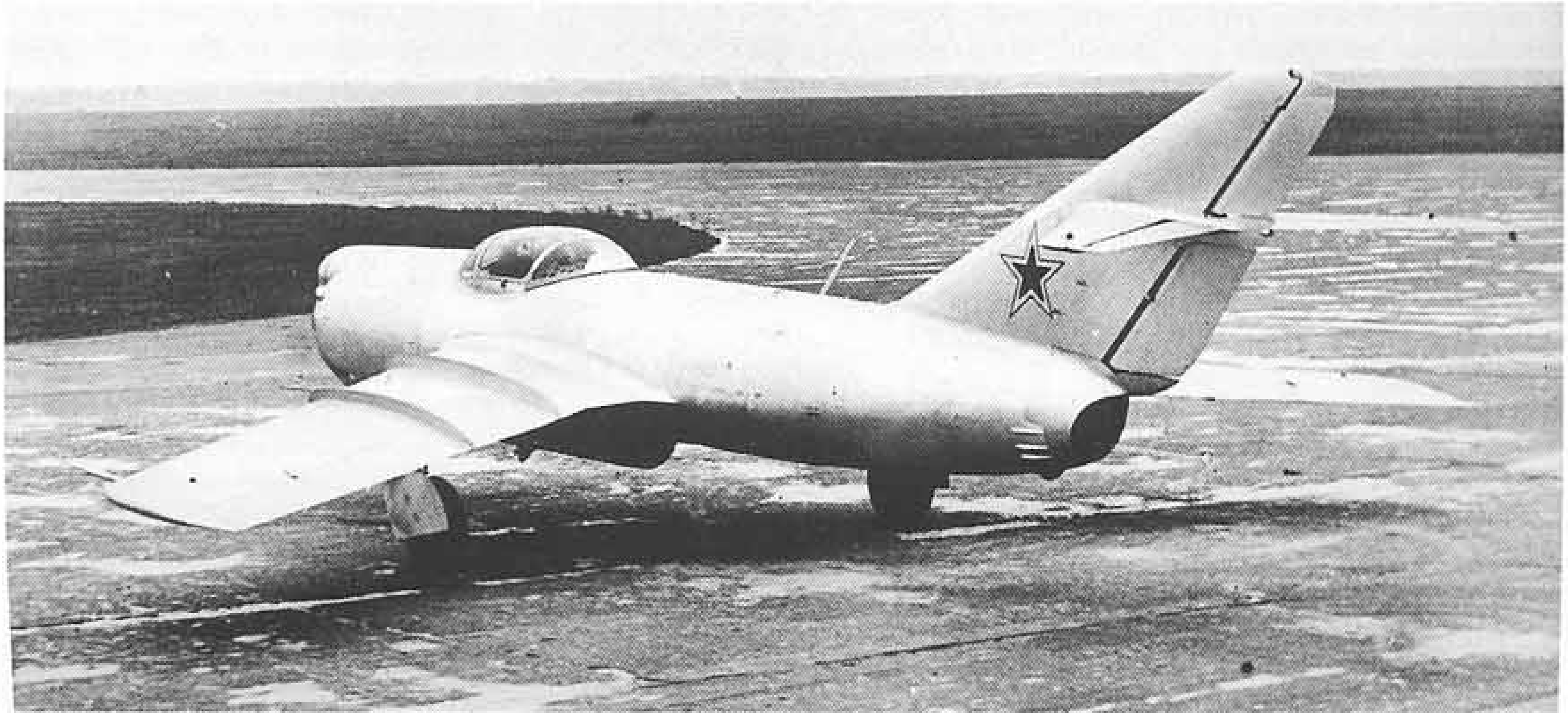
Span 14.2m (46ft 7in); length 15.775m (51ft 9in); wing area 41.2sq m (443.5sq ft).

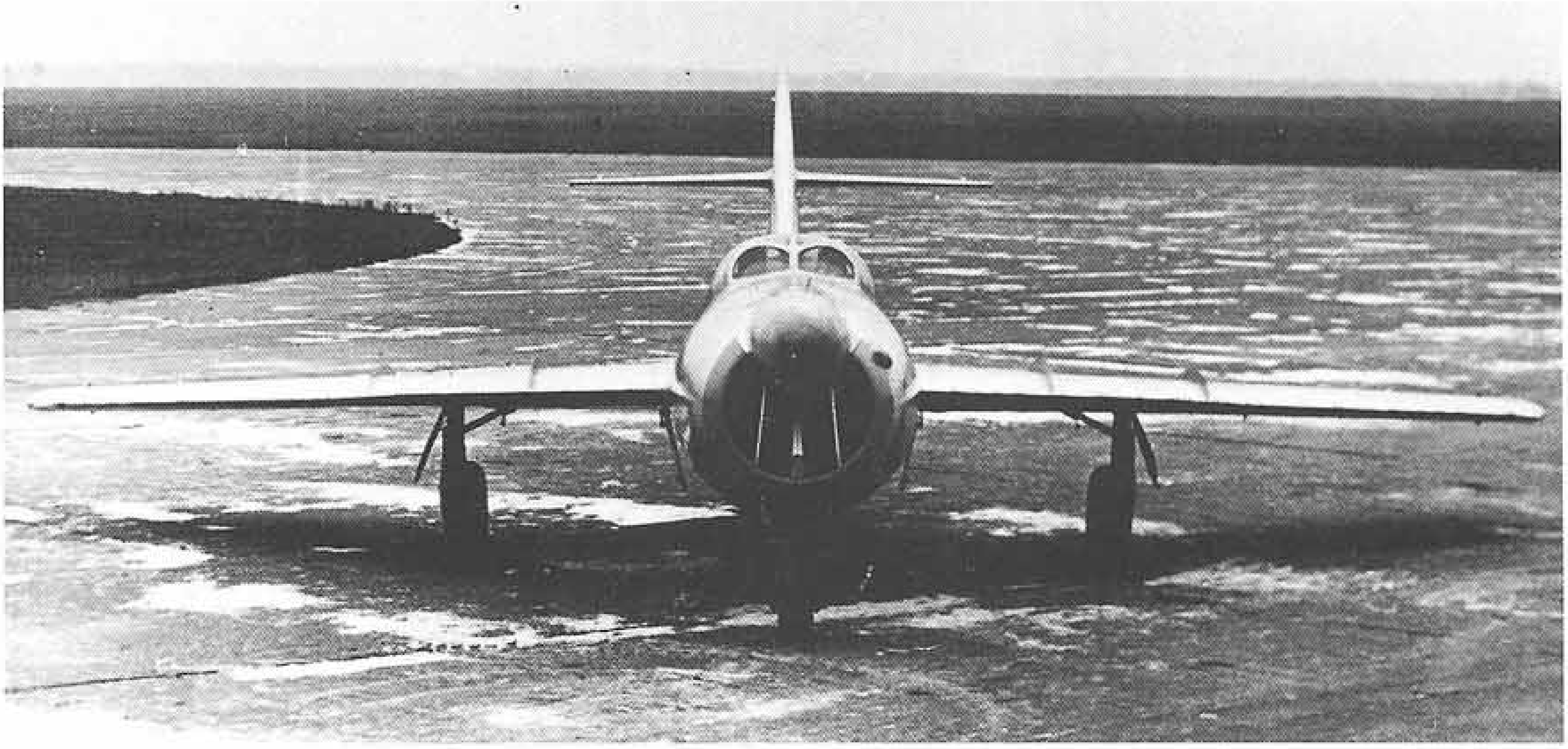
Weight empty 7,367kg (16,241lb); maximum fuel weight 2,700kg (5,952lb); weight loaded 10,265kg (22,630lb).

Maximum speed 1,040km/h (646mph) at sea level, 994km/h (618mph) at 10,000m (32,808ft); climb to 5,000m (16,404ft) 2.3min, to 10,000m 5.65min (Shavrov ascribes these figures to R-2); service ceiling 15,000m (49,213ft); range at high altitude (Shavrov) 1,205km (789 miles); takeoff run 610m (2,001ft); landing speed 185km/h (115mph); landing run 770m (2,526ft).

R-2

Outwardly identical to R-1, the R-2 was completed in November 1949. Its principal differences were that it was fitted with VK-1 engines, each rated at 2,700kg (5,952lb) thrust, operative *Toriy*-A radar, 750lit (165gal) slipper tanks under the wings, and a third N-37 gun, installed below the original right-hand gun. The windscreen and canopy were higher and the fixed rear transparent portion was larger, giving better all-round view, the canopy jet-





I-320, R-2. (OKB)

tison mechanism was improved, the airbrakes were stiffened by three external reinforcements and the airframe was fitted with de-icing (electrothermal round the nose and hot air along the leading edges of the wings and tailplanes). Avionics included RSIU-6 vhf (with a whip antenna replacing the R-1's wire), an RV-2 radar altimeter and *Bariy*-M IFF. Fitting the main radar reduced the design load factor to 7.5g, and the external tanks reduced it further to only 3.5g.

This aircraft was completed in November 1949, and began factory testing in December. In the course of one hundred flights it was spun, the canopy and the drop tanks were jettisoned, and the radar was replaced by the significantly better *Korshun* (kite). On 13 March 1950 a 37mm shell exploded before it reached the gun, and while the aircraft was being repaired the anhedral was halved to –1.5°, an additional fence was added ahead of the midspan of each aileron, a Mach-link was added to open the airbrakes automatically at 0.95, a bullet fairing was added behind the fin/tailplane junction, both jet-nozzle fairings were redesigned, the fin root was extended aft (reducing the height of the lower rudder) and, because roll instability persisted, the underwing spoilers were increased in span.

Redesignated as the **R-2mod** the aircraft resumed flying on 31 March 1950, and completed its factory tests in September 1950. The changed yaw/roll stability (a form of Dutch roll) resulted in a small ventral fin being added under the rear fuselage and the spoilers being interlinked with the ailerons. In the summer of 1950, when it was clear the I-320 would not go into production, Amet-Khan used the R-2mod as the testbed for the *Materik* (mainland) and *Magniy*-M (magnesium) ILS systems.

Dimensions unchanged.

Weight empty 7,827kg (17,255lb); fuel (with drop tanks) 3,927kg (8,658lb); weight loaded (clean) 10,725kg (23,644lb), (maximum) 12,095kg (26,664lb).

Maximum speed (clean) 1,090km/h (677mph) at 1,000m (3,280ft), 1,060km/h (659mph) at 10,000m (32,808ft); service ceiling 15,500m (50,853ft); range (Shavrov) 1,205km (749 miles), (with tanks) 1,940km (1,205 miles); landing speed 187km/h (116mph).

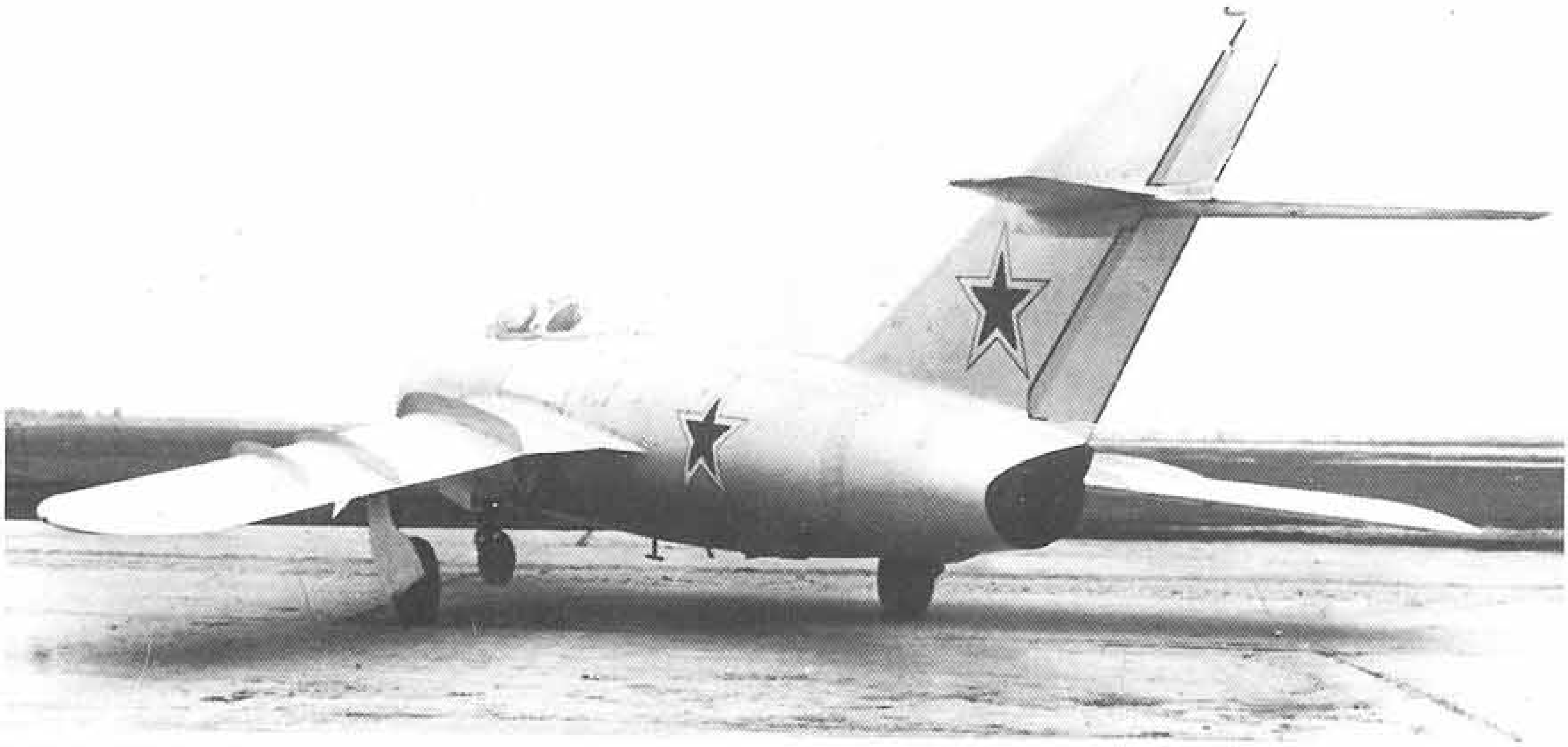
I-330, SI, MiG-17

In January 1949, when the MiG-15 was only just coming into full production, the MiG OKB decided that, while there was no immediate prospect of fitting a more powerful engine, the flight performance might be increased by aerodynamic changes. In particular, the transonic drag of the wing was expected to be significantly reduced by increasing the sweepback and reducing the ratio of thickness to chord. There was no chance of reducing thickness, but the very act of increasing sweepback automatically increased the root chord.

Aircraft SI accordingly took shape on the drawing boards at Factory No. 155 in the spring of 1949 with a completely new wing. As the intended sweep angle on the leading edge was 45°, the new aircraft was initially dubbed the MiG-15bis-45°.

In fact, the final design of wing was more complicated. The basic structure of the main section of fuselage, back to Frame 13 where the tail section was bolted on, was unchanged. The front and rear spars picked up as before at Frames 9 and 13, but because the greater sweep in effect moved the centre of pressure to the rear, extra area had to be added in front. This was achieved by extending the root forwards, increasing root chord from the 2.75m (108.2in) of the MiG-15 to 3.2m (126in). This increase in chord was maintained to the tip by adding at the trailing edge, so that the chord immediately inboard of the curved tip was increased from 1.5m (59in) to 1.7m (67in). Sweep angle at the trailing edge was zero from the root to the second rib and 40° from there to the tip.

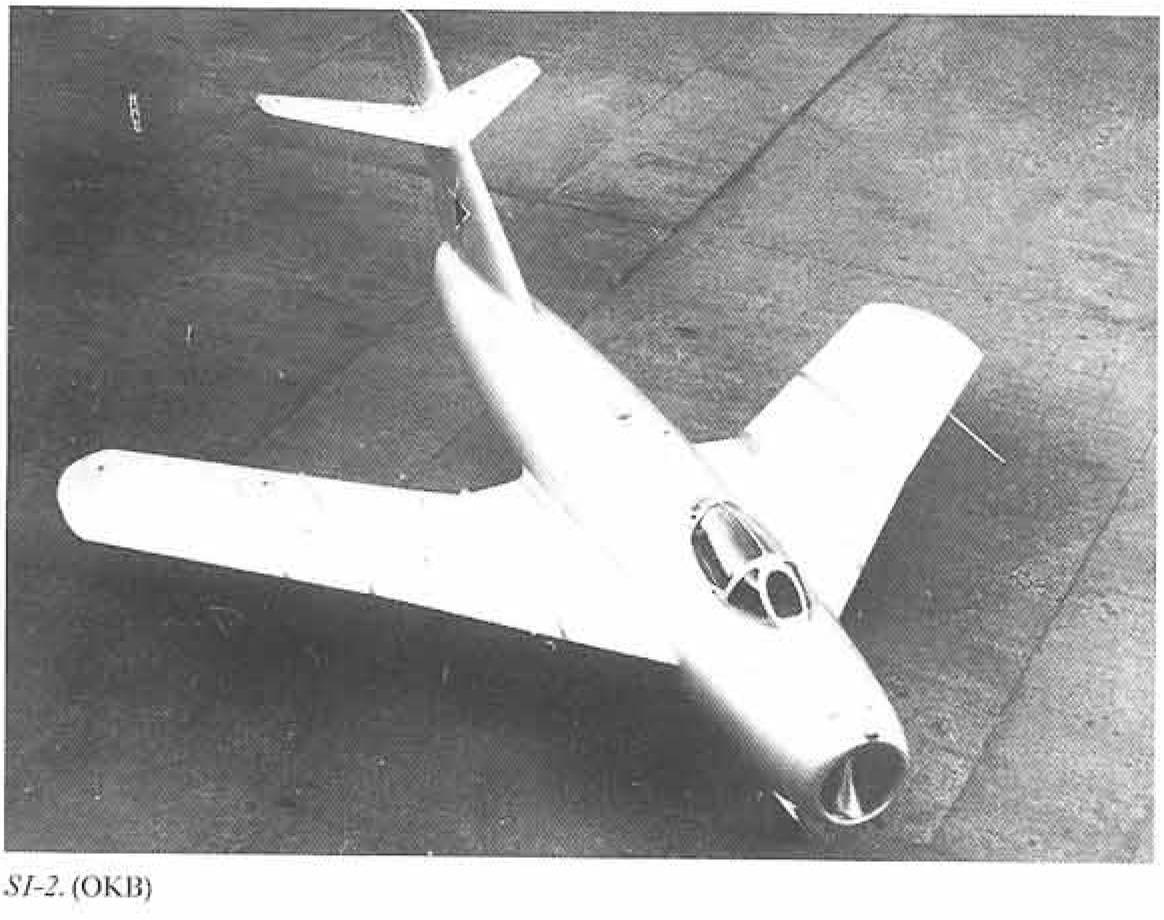
This increased the MAC (mean aerodynamic chord) to 2.19m (86.2in), improving thickness/chord ratio con-



SI-2, first MiG-17 to fly. (OKB)

siderably. Aerofoil profile was S-12s at the root and S-11 at the tip. Sweepback along the ¼-chord line was 45° to mid-semispan and 42° from there to the tip. Sweepback on the leading edge was 49° to mid-semispan and 45°30′ from there to the tip. Area was increased by just over 2sq m (21.5sq ft). Angle of incidence was 1°, and anhedral the same as for the R interceptor at –3°. Structurally the wings were little changed, there being 25 ribs and a total of nine stringers supporting the D-16ATV skin with a thickness of 1.2mm up to 3.5mm between the spars. There were three fences on each wing, the outermost being ahead of the ailerons, with a height of 110 to 125mm.

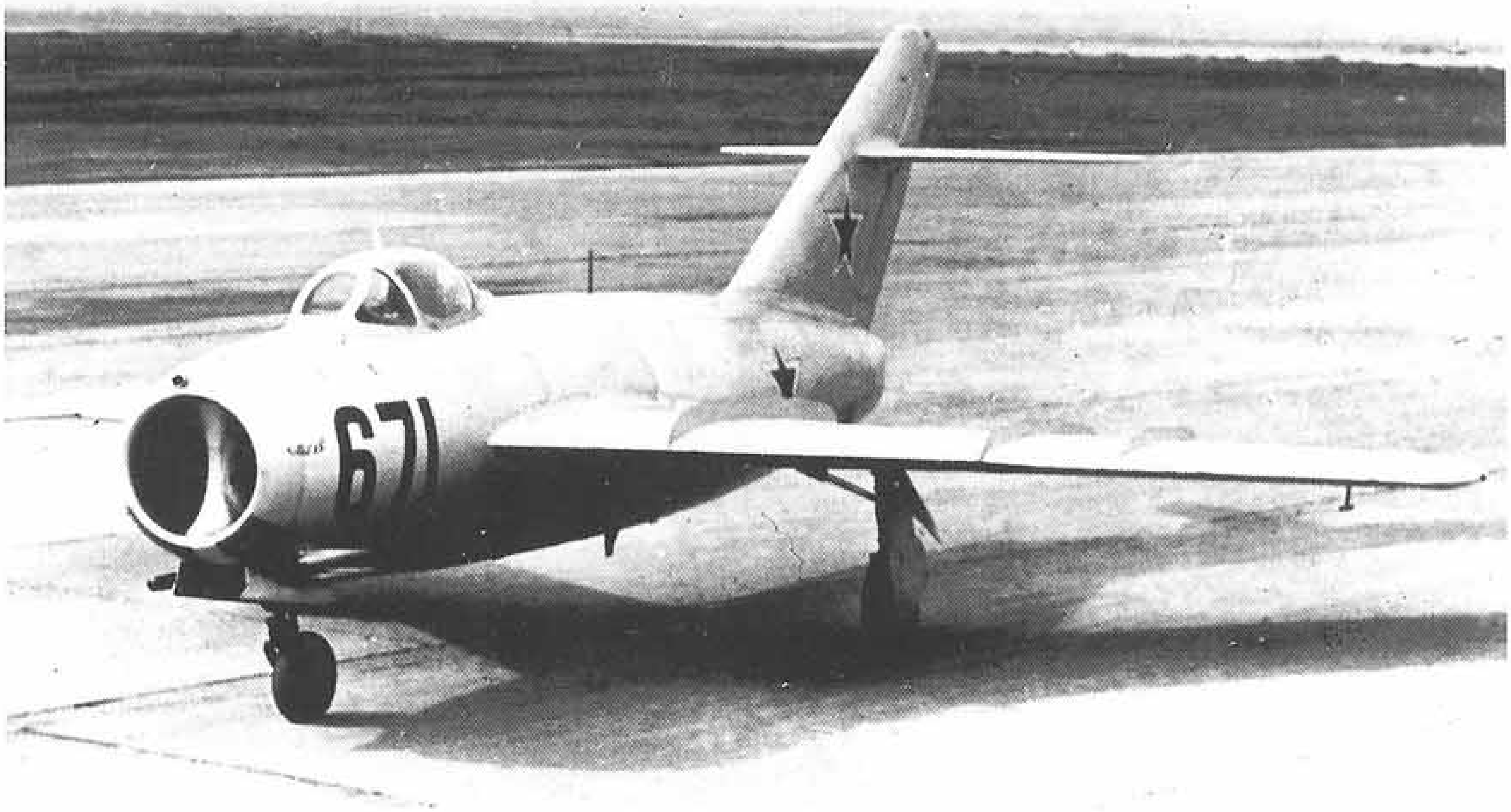
The new wing automatically increased the chord of the CAHI (Fowler) flaps whilst reducing their span (4m, 13ft 1½in, measured at 90° to the longitudinal axis). Area of each flap was 2.86sq m (30.79sq ft). They ran out hydraulically on tracks to 20° for takeoff and to the increased angle of 60° for landing. Because of their greater chord the ailerons were larger than those of the MiG-15. As before, the starboard aileron was tabbed. The lateral-control system was boosted by a BU-1U hydraulic ram ahead of the starboard front spar, the limits of aileron travel being ±18°.



SI-2. (OKB)

The rearward migration of the wing centre of pressure required a stretch of the rear fuselage in order to move the centre of gravity to match. Accordingly the removable rear section aft of Frame 13A was lengthened by 0.9m (35.4in), and this automatically improved drag at high Mach numbers. The vertical tail was geometrically unchanged apart from a slight increase in area to 4.26sq m (45.86sq ft), including 0.947sq m (10.19sq ft) for the rudders; the leading-edge sweep of 55°41′ simply means that the '56°' given for the MiG-15 was a rough rounding-up of the exact figure. The horizontal tail was increased in sweep to 45° on the leading edge, reducing span from 3.25m to 3.18m (10ft 5¼in). Chord was increased to give the slightly greater total area of 3.1sq m (33.37sq ft), including 0.884sq m (9.52sq ft) for the elevators. As before, there was a tab on the port elevator. Profile of the horizontal tail was NACA-M. Elevator boost was unchanged, limits of travel being 32° up and 16° down.

The extended rear fuselage was fitted with a small underfin which incorporated a steel-shod bumper. The airbrakes were changed in shape, being made longer and narrower. The



SI-02, third MiG-17. (OKB)

area of each brake was unchanged, 1.76 sq m being the area of both combined. Maximum airbrake angle was also unchanged at 55°.

The fuel system was hardly altered. There remained three tanks as before, Nos. 1 and 2 (resin flexible cells with a combined capacity of 1,240 litres (273gal) including the 30lit inverted-flight compartment) in the main fuselage between Frames 9 and 13 and the No. 3 metal tank under the jetpipe, with a capacity of 168 litres (37gal). As before, two 400lit drop tanks could be carried. The landing gear was unchanged, though the new wing increased wheelbase to 3.368m (132.6in) and slightly reduced track to 3.849m (151.5in). Tyre pressures were up to 8.5kg/sq cm (121lb/sq in) for the 660 × 160mm main tyres and up to 4.2kg/sq cm (59.7lb/sq in) on the 480 × 200mm nose unit, which had a castoring (but not steering) angle of ±50°.

Armament was as before: one N-37D with 40 rounds and two NR-23 with 80 rounds each, all on a demountable tray, charged electro-pneumatically and fired by separate buttons on the control column. The sight in series MiG-17s was the ASP-4NM, backed up by the S-13 combat camera and, for training, a PKP-2 camera looking through the gunsight. Though not fitted to the prototypes, the D4-50 underwing rack could be fitted to carry bombs from 50 to 250kg (551lb), or rocket launchers, or pairs of TRS-190 rockets, or single ARS-212 rockets.

As in the MiG-15, the landing gear, flaps and airbrakes were operated by a hydraulic system with a cutout pressure of 140kg/sq cm (1,991lb/sq in); the aileron and elevator boosters were in a separate circuit operating at 65kg/sq cm (925lb/sq in). The main pneumatic circuit, charged to 130kg/sq cm (1,849lb/sq in), operated the wheel brakes, cannon charging, canopy sealing and inflation of the PPK-1 anti-g suit. The back-up system, at the same pressure, provided emergency extension of the landing gear and flaps and standby wheel brakes.

An engine-driven GSR-3000 generator provided d.c. current at 28.5V to charge the 12SAM-25 battery. Services included the heated nose ring (the windscreen was anti-iced by 3 litres of ethyl alcohol), engine starting, numerous electrically driven switches and valves, instruments and avionics. The latter included RSIU-3M *Klyon* or RSIU-4M vhf, OSP ILS (comprising ARK-5 ADF, MRP-48P marker and RV-2 radar altimeter) and SRO-1 *Bariy*-M IFF. Later series aircraft were fitted with a *Sirena*-2 radar warning receiver covering the rear hemisphere, and an ESKR-46 box housing four flares.

SI-1 was a static-test airframe. SI-2 was completed at the end of 1949 and first flown by Ivan T Ivashchenko on 13 January 1950. The aircraft proved excellent, and on 1 February Ivashchenko reached 1,114km/h (692mph) in level flight, which in the exceedingly cold atmosphere was equivalent to Mach 1.03. The rapid progress was not to last. On 20 March Ivashchenko was letting down after a test flight when the SI-2 went into an ever-steepening dive, going straight into the ground. Data for SI-2.

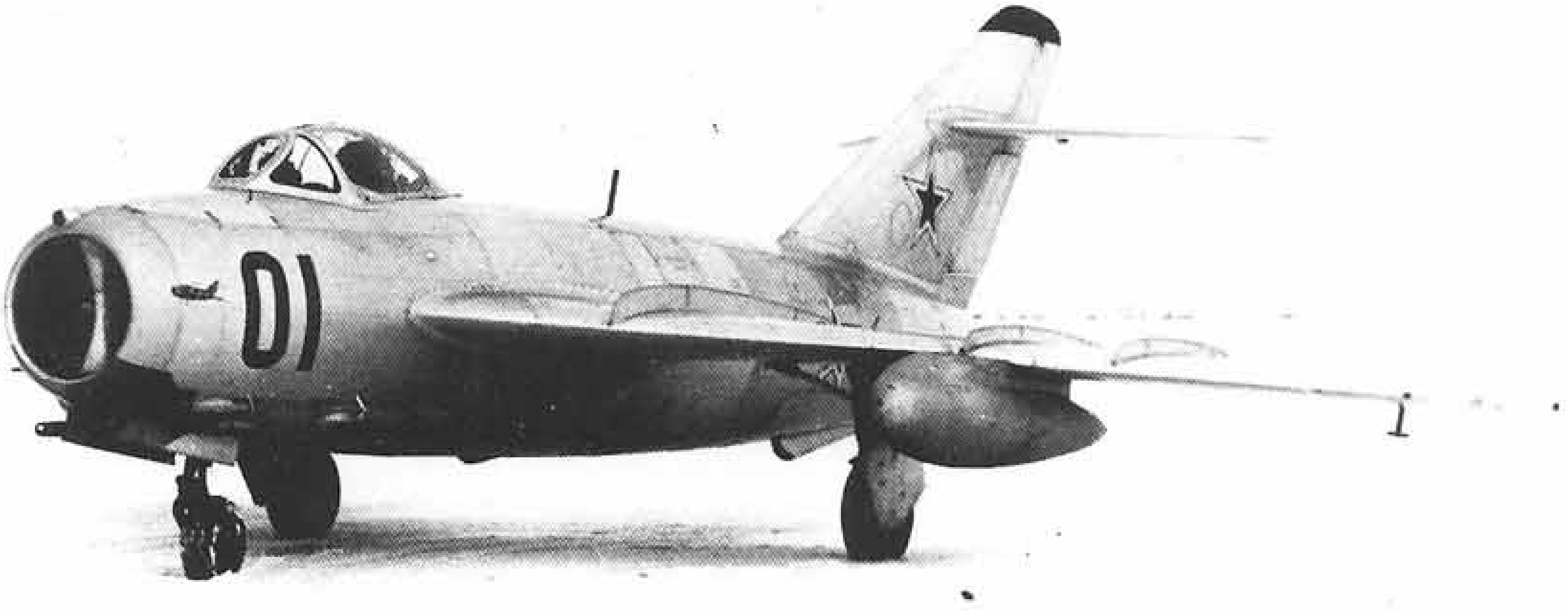
Span 9.628m (31ft 7in); length 11.26m (36ft 11½in); wing area 22.64sq m (243.7sq ft).

Weight empty 3,615kg (7,970lb); internal fuel/oil 1,200kg (2,646lb); weight loaded (clean) 5,050kg (11,133lb); maximum takeoff weight 5,480kg (12,081lb).

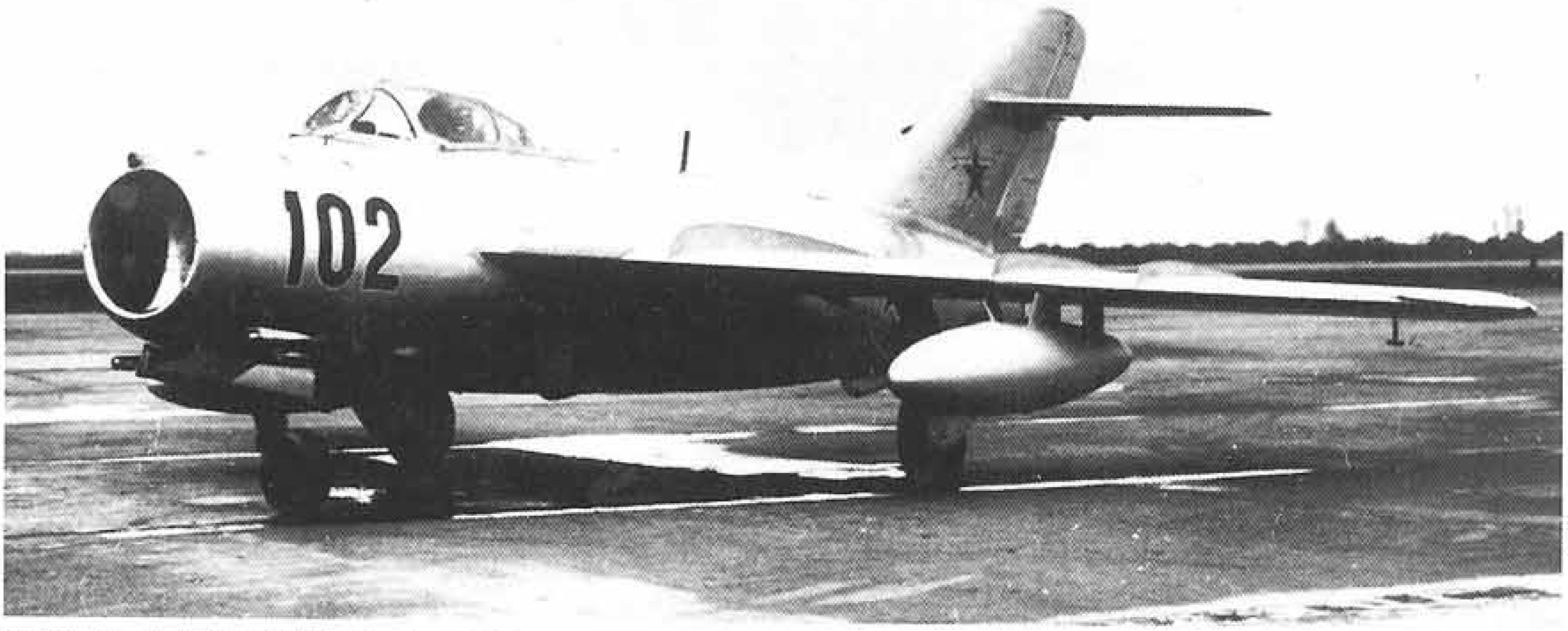
Maximum speed 1,152km/h (716mph) at sea level, 1,161km/h (721mph) at 5,000m (16,404ft); climb to 5,000m (16,404ft) 2min, to 10,000m (32,808ft) 4.9min; service ceiling 16,000m (52,495ft); range (clean) 1,200km (746 miles), range (with 400lit drop tanks) 1,570km (976 miles); takeoff run 500m (1,640ft); landing speed 159km/h (99mph); landing run 650m (2,133ft).

MiG-17

Discovering the causes (initially, a fault in the elevator circuit) and continuing with modified prototypes set the SI programme back a year. SI-3



SI-01 with new fin cap and tanks. (OKB)



SI-01 improved, 'Red 102'. (Yefim Gordon archive)

was never built, and the prototype shop built two new aircraft, SI-01 and SI-02. SI-01 was delayed, and SI-02 resumed the flight-test programme on an unknown date in spring 1951, in the hands of VVS pilot Grigoriy A Sedov, who was hired by the OKB and was soon to join the staff. Progress was very rapid, and NII-VVS State testing was successfully completed on 20 June 1951. During LII testing S N Anokhin and P I Kazmin each reached Mach 1.14 in dives, though in service the Mach limit was 0.95. On 1 September 1951 the MAP ordered the SI to be built in series as the MiG-17, at five factories:

Gor'kiy (now Nizhniy-Novgorod)	2,424
Komsomolsk-na-Amur	2,180
Kuibyshev (Samara)	392
Novosibirsk	2,167
Tbilisi	836
Total (Soviet Union)	7,999
Czechoslovakia	457
Poland	540
China (single-seat)	767
JJ-5/FT-5	1,061
Total (all versions)	10,824

The sheer momentum of MiG-15 production delayed the switch to the MiG-17 until late 1953. In VVS service the MiG-17 was very popular, with marginally higher speeds, much better climb and even better manoeuvrability. Increased takeoff and landing speeds were not considered to require lengthening of runways. From 1966 the Chinese F-4 version was encountered by US fighters over North Vietnam. Though seemingly obsolete, these simple aircraft proved hard to deal with under the rules which prohibited BVR (beyond visual range) kills. Brig-Gen Robin Olds, the most experienced US fighter pilot in the theatre, said 'Unlike the chairborne strategists in the Pentagon, and their computer analysis, I can say that the MiG-17 is a very dangerous little animal. Its manoeuvrability is phenomenal! It is difficult to outmanoeuvre it with an F-4 Phantom'.

Red-nosed MiG-17 at LII with armament tray lowered. (Yefim Gordon archive)

During the course of production many modifications were made. The VK-1 engine was soon replaced by the VK-1A, with the same takeoff rating (2,700kg, 5,952lb) but longer TBO and much extended overall life. The seat was fitted with leg restraint straps and improved ejection triggers, first on both armrests and finally with a faceblind, and it was stabilized by adding fins. The standard 400lit (880gal) drop tanks, initially 2.81m long, were extended to 3.01m (118.5in) and attached by a three-strut pylon, and the fuel feed from the drop tanks was stabilized at high speeds by fitting pressure-relief valves in the tank-pressurization pipes. For attack on surface targets a second pair of pylons could be added 3.2m (10ft 6in) from the centreline, to carry the LR-130 rocket or various other loads. The landing light in the inlet splitter was replaced by a retractable light in the centre of the port wing. Later series MiG-17s had a one-piece canopy with no fixed rear portion, and an improved rear-view periscope.

Including Czechoslovak and (especially) Chinese versions, the MiG-17 served with 42 air forces: Afghanistan, Albania, Algeria, Angola, Bulgaria, Cambodia, China, Congo, Cuba, Czechoslovakia, Egypt, Ethiopia, Finland, the German Democratic Republic, Guinea, Guinea-Bissau, Hungary, India, Indonesia, Iraq, Malagasy, Mali, Mongolia, Morocco, Mozambique, Nigeria, North Korea, North Vietnam/Vietnam, North Yemen, Pakistan, Poland, Romania, Somalia, South Yemen, Soviet Union, Sri Lanka, Sudan, Syria, Tanzania, Uganda and Yugoslavia.

Dimensions as SI-2.

Weight empty (typical) 3,798kg (8,373lb); fuel/oil 1,173kg (2,586lb); weight loaded (clean) 5,202kg (11,468lb); maximum takeoff weight 5,932kg (13,078lb) (Shavrov states 6,072kg, 13,386lb).

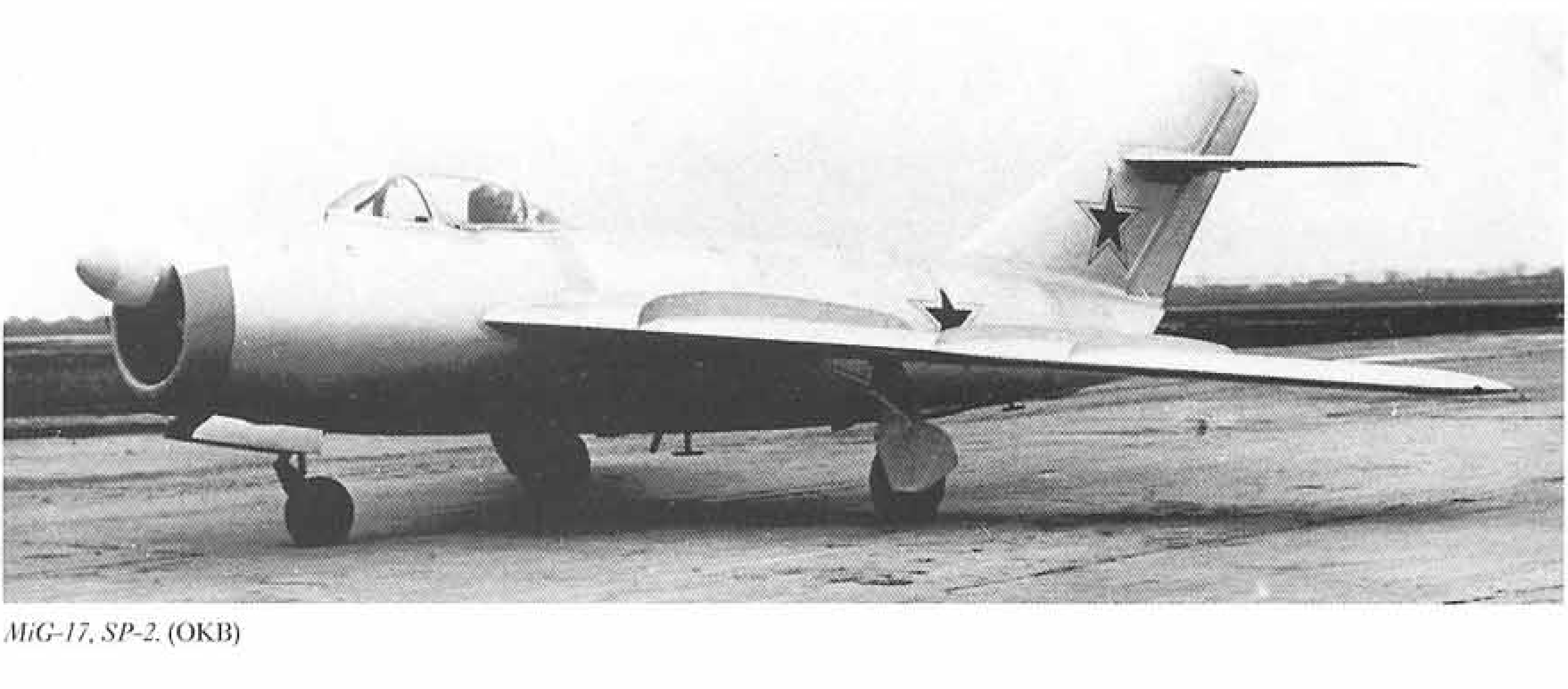
Maximum speed at sea level 1,060km/h (659mph), at 2,000m (6,561ft) 1,114km/h (692mph); climb to 5,000m (16,404ft) 2.1min, to 10,000m (32,808ft) 5.1min; service ceiling 15,600m (51,180ft); range (clean) 1,295km (805 miles) (Shavrov, 1,165km), (with 400lit drop tanks) 2,150km (1,336 miles) (Shavrov, 1,735km, a remarkable discrepancy); takeoff speed and run 230km/h (143mph)/550m (1,804ft); landing speed 180km/h (112mph); landing run 850m, (2,789ft).

SP-2

Chronologically, this was the next major variant, though it was a single experimental aircraft which introduced two completely new features. One was the afterburning VK-1F engine, described in the section on the SF/MiG-17F. The other was the *Korshun* interception radar, previously fitted to the I-320 R-2/R-3. An identical installation was fitted in the nose of the SP-2, but with the S-13 camera on the right side and a rather cramped cartesian display on the cockpit centreline viewed by the pilot through a visor.

Other modifications in the SP-2 included removing the N-37D and increasing the NR-23 magazine capacity to 120 rounds each; balancing the mass of the radar by enlarging tank No. 3 under the jetpipe to 195 litres (43gal); and linking the airbrakes to the Machmeter to open automatically at 1.03.

Factory tests were done by Sedov from March to November 1951. This may have been the first aircraft flown for the OKB by Sedov, and it is extraordinary that this afterburning radar-equipped prototype should have predated both the radar-equipped SP-7 with the original engine and also the SF prototype of the MiG-17F! From



MiG-17, SP-2. (OKB)

28 November to 29 December 1951 the SP-2 completed NII-VVS trials, in which it was judged adequate in performance but too difficult for the pilot to effect interceptions single-handed. The NII-VVS pilots had previously considered the I-320 difficult enough, even with a second man to concentrate on the *Korshun* radar.

Dimensions unchanged except length 11.85m (38ft 10¼in).

Weight empty 4,010kg (8,840lb); fuel and oil 1,210kg (2,668lb); weight loaded (clean) 5,550kg (12,235lb).

Maximum speed at 3,000m (9,842ft) 1,109km/h (689mph); climb to 5,000m (16,404ft) 2min, 10,000m (32,808ft) 5.2min; service ceiling 15,200m (49,870ft); range (no tanks) 1,375km (854 miles); takeoff run 765m (2,510ft); landing run 805m (2,641ft).

MiG-17P, SP-7

Chronologically, this interceptor prototype comes next, though the start of its factory testing in summer 1951 is not recorded. It was a minimum-change conversion of a MiG-17, with the VK-1A engine. The radar was the RP-1 *Izumrud*, which had already been fitted to the MiG-15 SP-5. As in that aircraft, the scanning antenna was in the top of the inlet lip and the tracking/ranging dish in a small radome in the centre of the inlet. Armament comprised three NR-23 guns with 100 rounds each, aimed by an ASP-3NM sight. The BU-1U aileron booster was unchanged.

Sedov was again the OKB pilot, and he completed factory testing in summer 1952. Following NII-VVS testing, the SP-7 was certified and put into production as the MiG-17P. The series aircraft had airbrakes enlarged to 0.97 sq m (10.4 sq ft), and some (possibly most) had only two guns, one on each side. The MiG-17P was the first radar-equipped interceptor to go into service in the Soviet Union. From the winter 1953–54 it served with the IA-PVO, chiefly in Azerbaijan and Kazakhstan, and with the interceptor regiments of the A-VMF (naval aviation). Pilot training was found to be very difficult, mainly because of the workload in any interception requiring the radar. On a clear night this aircraft could find a Tu-4 at 9.5km (5.9 miles). The view over the nose on the landing approach was worse, and in the end the MiG-17P was flown only by above-average pilots.

Dimensions unchanged except length 11.68m (38ft 3⅞in) (Shavrov, 11.36m).

Weight empty 4,154kg (9,158lb); fuel/oil 1,210kg (2,668lb); weight loaded 5,550kg (12,235lb); maximum takeoff weight (two 400lit tanks) 6,280kg (13,845lb).

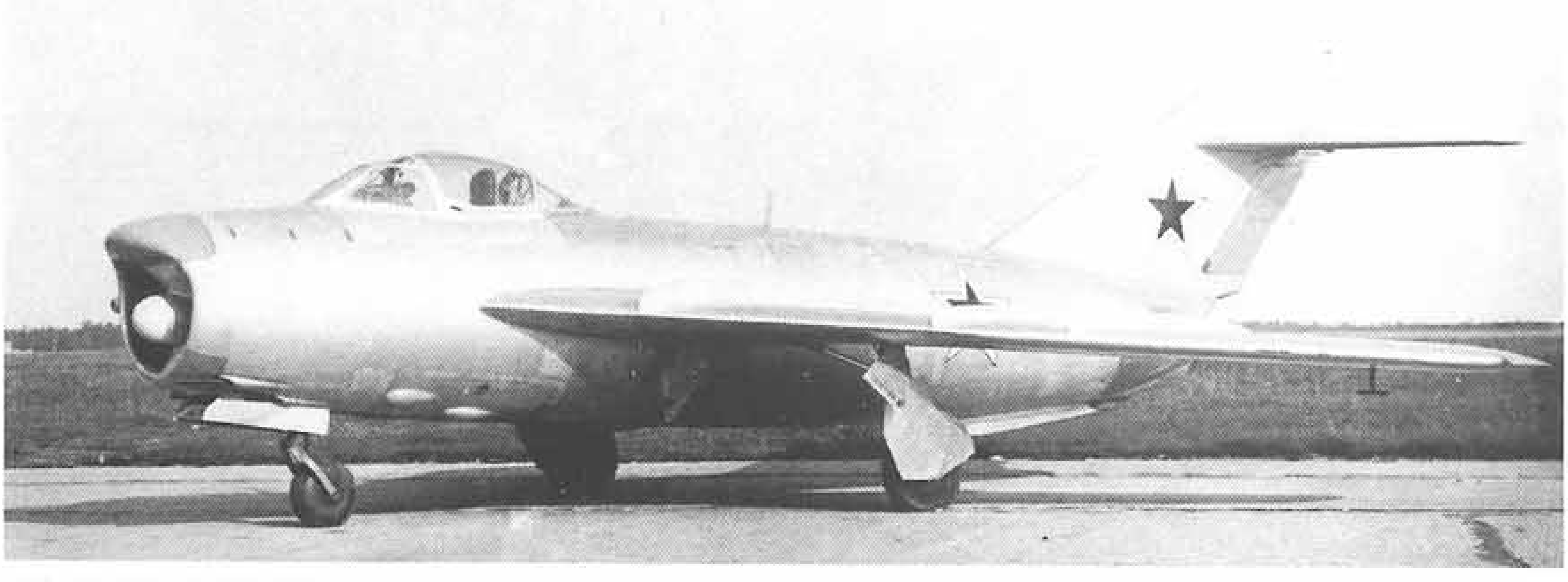
Maximum speed at sea level 1,060km/h (659mph), at 3,000m (9,842ft) 1,115km/h (693mph); climb to 5,000m (16,404ft) 2.5 min, to 10,000m (32,808ft) 6.6min, to 14,000m (45,932ft) 16.2min; service ceiling (Shavrov) 14,500m (47,575ft); range 1,290km (802 miles), (with two 400lit tanks) 2,060km (1,280 miles); takeoff run 630–805m (2,067–2,641ft); landing speed 195km/h (121mph); landing run 860m (2,822ft) (Shavrov 885m).

MiG-17F, SF

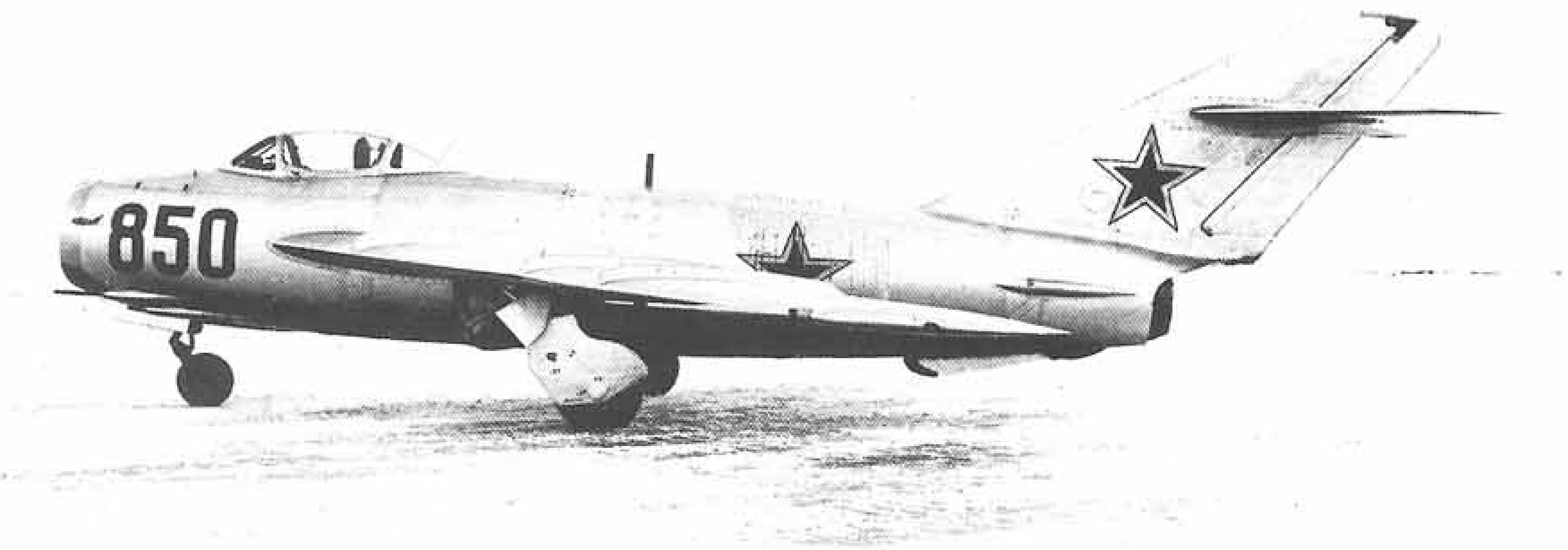
Though the MiG-17 had a good performance, addition of radar made the MiG-17P relatively sluggish, and in any case there was unceasing pressure to make fighters still faster. Pending the development of new engines, the obvious immediate solution was to fit the VK-1 with an afterburner.

According to some reports this was done by the MiG OKB, assisted by CIAM, but – though the aircraft designers did experiment with such a development – the afterburning VK-1F was of course designed and developed at the Klimov engine KB, where it first ran in January 1951. Considerable effort was needed to perfect combustion in the enlarged jetpipe, and the mechanical design of the variable-area propelling nozzle. The ultimate design of nozzle comprised eight petals driven by two hydraulic rams to open the final diameter from the original 540mm (21.26in) to 624mm (24.57in). Presence of the flameholder reduced dry maximum thrust to 2,600kg (5,732lb), but maximum reheat increased this to 3,380kg (7,451lb). The VK-1F remained in production to 1958, about 20,000 being made not only in the USSR but also in Czechoslovakia, Poland and China.

Fitting the VK-1F to the MiG-17 required modifications to Frames 18 and 19 and redesign of the rear fuselage from Frames 20 to 30. An obvious modification was to cut back the fuselage to the rear fin spar, leaving a much larger aperture through which the variable nozzle projected, faired by a long 'pen nib' under the rudder. Even more obvious changes were to add a ventral bumper strake under the rear fuselage and totally redesign the airbrakes, retaining the increased area of 0.98 sq m (10.55 sq ft), and the 55° movement, but making them shorter and occupying almost the full depth of



MiG-17P, SP-7. (RART/GP)



First MiG-17F prototype (rebuilt MiG-15bis), OKB logo on nose. (OKB)

the rear fuselage. The airbrake operating rams were raised level with the fuselage horizontal centreline, and their blister fairings extended to the cutback tail end. Other modifications included a high-capacity afterburner fuel pump and new piping, and an electrical control system for the reheat fuel and nozzle.

Armament and avionics were unchanged, apart from fitting the ASP-4NM gunsight through which looked an FKP-2 monitoring camera. The usual radio was the RSIU-4V vhf, with a sloping blade antenna beside the rear canopy fairing.

The re-engined fighter was designated MiG-17F. The first, callsign '850', began factory testing in the hands of Chernoburov on 29 September 1951. OKB testing was completed on 16 February 1952, after which very successful NII-VVS trials followed. The MiG-17F began to replace the MiG-17 in production in November 1952, and it was by far the most important production version.

Successive series introduced modifications. From Aircraft 10-96 the negative-g fuel collector tank was fitted with six nonreturn valves to handle the full flow at low level in afterburner. Later, about Series 50, the cockpit was fitted with a cold-air unit with automatic temperature control. The PPK-1 anti-g suit was made standard, and supplied with air through an AD-5 valve sensitive to g-load. The afterburner nozzle was fitted with the new GA-13M/3 automatic hydraulic-control valve. The nose landing-gear unit was improved, and fitted with an emergency extension system. The seat was fitted with improved stabilization and a new faceblind. From Aircraft No. 414351 the SRD-1 radar ranger was fitted, linked to the gunsight, and the *Sirena*-2 radar warning receiver was installed.

In summer 1959 NII-VVS tested a MiG-17F in the fighter-bomber role. A D4-50 universal attachment beam was added under each wing between the landing-gear units and the pylon for the 400lit tank. On this could be hung bombs up to FAB-250 size, or a rocket launcher and two 190mm rockets or a single 212mm rocket. Without tanks it was possible to carry two rocket launchers and two bombs.

MiG-17F, SF-3; this prototype was fitted with two NR-30 guns. (Yefim Gordon archive)

These could be released horizontally, or in a steep dive, or in a forward or over-the-shoulder toss. After 1960 some export MiG-17F fighters were armed with R-3S AAMs.

Maximum load factor for all versions, in the clean condition, was 8g. With full tanks fitted this was reduced to 4.5g, which was relaxed to 6.5g with the drop tanks retained but empty. The ASCC reporting name was 'Fresco-C'.

Dimensions unchanged.

Weight empty (normal) 3,940kg (8,686lb); fuel/oil 1,155–1,170kg (2,546–2,579lb); weight loaded (clean) 5,340kg (11,772lb), (maximum) 6,069kg (13,380lb); maximum landing weight 4,164kg (9,180lb).

Maximum speed with reheat at sea level 1,100km/h (684mph), at 3,000m (9,842ft) 1,145km/h (711.5mph), at 5,000m (16,404ft) 1,130km/h (702mph), at 10,000m (32,808ft) 1,071km/h (666mph), at 12,000m (39,370ft) 1,054km/h (655mph); in MIL (maximum dry) thrust at sea level 1,097km/h (682mph), at 3,000m (9,842ft) 1,100km/h (684mph); limit with tanks 940km/h (584mph); Mach limit (clean) 1.03 to June 1954, 1.15 above 7,000m (22,966ft) subsequently; climb with reheat, to 5,000m (16,404ft) 1.8min, to 10,000m (32,808ft) 3.7min, to 14,000m 8.3min; climb in MIL thrust, to 5,000m (16,404ft) 2.4min, to 10,000m (32,808ft) 6.2min, to 14,000m (45,932ft) 14min; service ceiling (reheat, still climbing at 3.6m/s) 16,600m (54,462ft); range at 12,000m (39,370ft), 1,240km (771 miles) clean, 2,020km (1,255 miles) with tanks; range at 12,000m using reheat to climb first 3,000m, 1,160km (721 miles) clean, 1,940km (1,205 miles) with tanks; takeoff speed 235km/h (146mph), takeoff run 590m (1,936ft); landing speed 170–190km/h (106–118mph); landing run 850m (2,789ft).

SR-2

Chronologically, the next prototype was the SM-1, I-340, but this twin-engined aircraft is treated later as a stepping-stone to the MiG-19. Accordingly, the next to be described here is the SR-2, which was not only a prototype of a reconnaissance version but also was powered by a new engine. Determined to wring everything possible out of the excellent British Nene, in 1949 Klimov ran the prototype VK-5, with a remarkable increase in turbine inlet temperature and a modest increase in mass flow. By late 1951 this engine was rated at 3,000kg (6,614lb) dry and 3,850kg (8,488lb) with afterburner.

The forward fuselage was redesigned to carry reconnaissance equipment. The gun pack was eliminated and replaced by two NR-23 guns fixed conventionally, one on each side with the barrel faired outside the fuselage, each with 100 rounds. Under the cockpit was installed an AFA-BA-21s or AFA-BA-40R camera on a mounting which could be controlled to give vertical, oblique or overlapping twin-strip pictures. The aperture in the fuselage skin was covered by twin doors, opened before the photographic run. The pilot had a MAG-9 voice wire recorder. An additional modification was that, to gain experience, the OKB used this aircraft as the testbed for a servo-powered elevator with feedback, replacing the usual simple hydraulic boost.

The SR-2 was completed in May 1952, with callsign 'Red 404'. Factory testing was begun by Chernoburov in June. NII-VVS testing proceeded in parallel. To some degree because of engine problems OKB testing was not completed until January 1954, and State testing on 10 August 1954. The NII-VVS report rated the aircraft satisfactory, but said there was no justification in adopting the immature engine for a small increment in performance. It recommended production of a MiG-17R with the VK-1F engine.

As recommended in the NII-VVS report on the SR-2, a number of MiG-17F aircraft were built with exactly the same forward fuselage as the SR-2. Surprisingly, the Service designation was not the obvious one of MiG-17R but MiG-17F, the suffix in this case confusingly standing for *foto*. The data were similar to those of the MiG-17F fighter.

Dimensions unchanged.

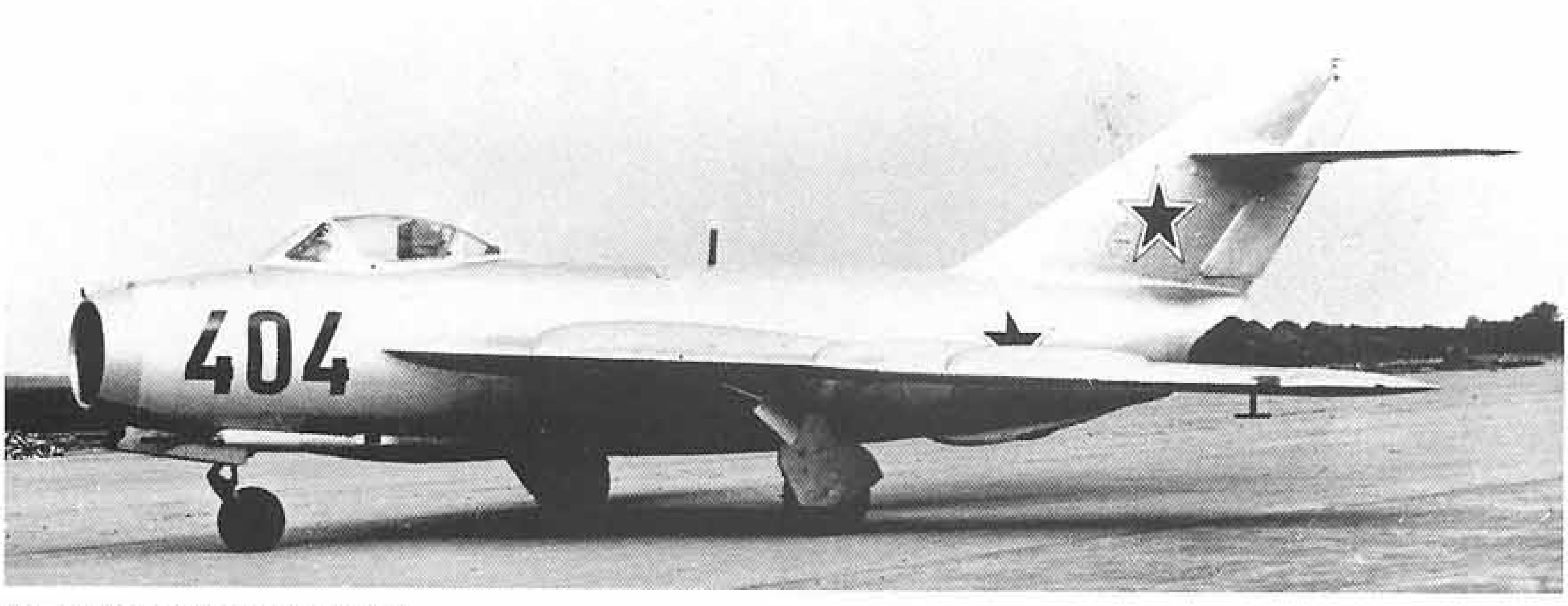
Weights unknown except loaded (clean) 5,350kg (11,795lb).

Maximum speed 1,132km/h (703mph) at unstated height; climb to 5,000m (16,404ft) 2 min; service ceiling 16,800m (55,118ft); range with two 600lit drop tanks 2,115km (1,314 miles).

MiG-17PF, SP-7F

Having switched to the afterburning VK-1F engine, in order to restore performance lost by fitting radar, the next stage was to fit the new engine to the MiG-17P. The result was naturally called the MiG-17PF.

Essentially, the rear fuselage was similar to that of the MiG-17F, while the rest of the aircraft resembled the MiG-17P. Among the modifications were that the engine drove an uprated electric generator, designated GSR-6000, meaning 6kW, the twenty-four replaceable units forming the radar were rearranged (among other changes, units 4 and 8 were placed in the cockpit), and to improve centre-of-gravity position the 12SAM-25 battery was moved from the nose to the root of the fin. The gunsight incorpo-



MiG-17, SR-2. (Yefim Gordon archive)

MiG-17PF in service with IA-PVO. (Yefim Gordon archive)

rated SRD-1M radar ranging, the *Sirena*-2 RWR was fitted, and series MiG-17PF aircraft were fitted with the NI-50B ground-position indicator to assist bad-weather navigation.

The SP-7F prototype began factory testing in November 1952, and passed NII-VVS testing in the following year. In late 1953 it replaced the MiG-17P in production. It served with the IA-PVO and, in 1955–59, with the Czechoslovak Air Force. In Poland it was made under licence, as described later. From the twenty-fifth aircraft of the sixth series the radar was the RP-5 *Izumrud*, with radomes which both projected slightly further in front (though brochure figure for aircraft length was unchanged). This radar extended typical detection range against a large target to 12km (7.5 miles). Like the MiG-17P, the ASCC reporting name was 'Fresco-D'.

Dimensions as MiG-17P.

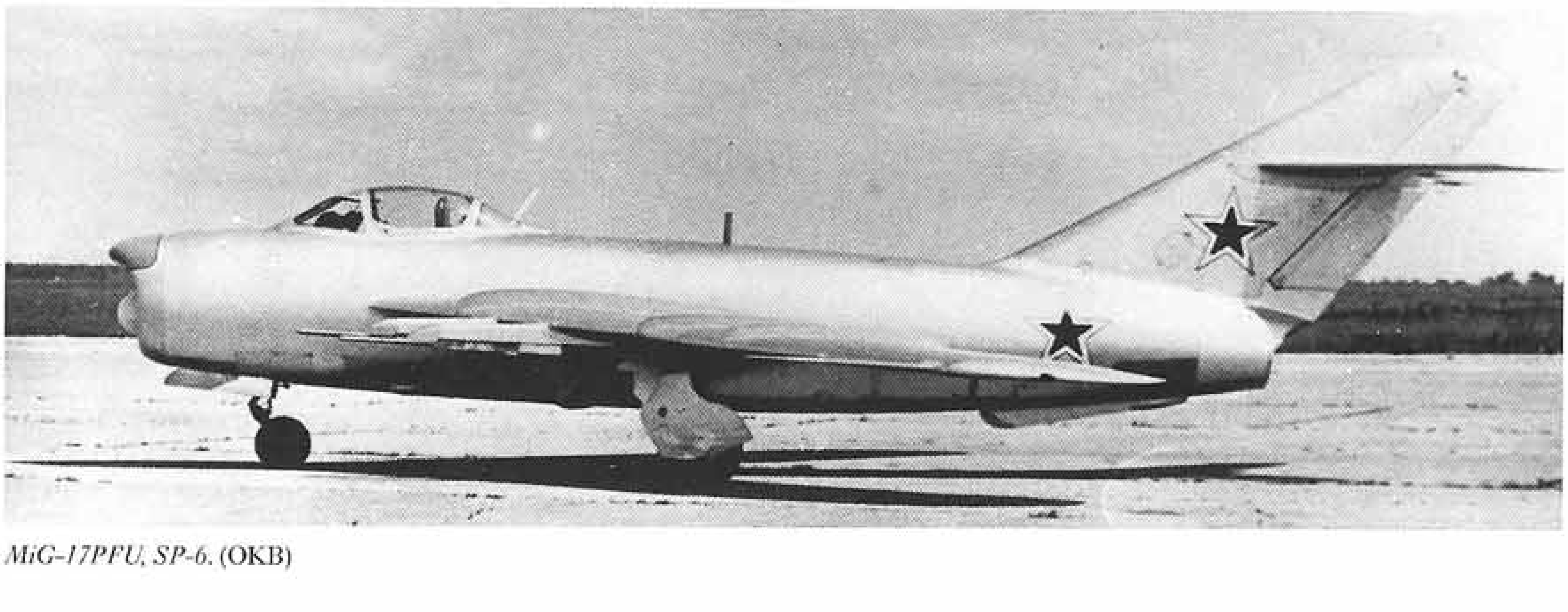
Weight empty 4,182kg (9,220lb); internal fuel/oil 1,143kg (2,520lb); weight loaded (clean) 5,620kg (12,390lb); maximum takeoff weight with 400lit tanks (first series) 6,280kg (13,845lb), remainder 6,330kg (13,955lb).

Maximum speed (with reheat) 1,123km/h (698mph) at 3,000m (9,842ft), 1,121km/h (696.5mph) at 4,000m (13,123ft), maximum speed (MIL thrust) 1,074km/h (667mph) at 4,000m (13,123ft), 1,038km/h (645mph) at 12,000m (39,370ft); climb to 5,000m (16,404ft) (reheat) 1.9min, (MIL) 3.1min; climb to 10,000m (32,808ft) (reheat) 4.5min, (MIL) 7.6min; service ceiling 15,850m (52,000ft); range (high altitude) 1,100km (684 miles), (with 400lit tanks) 1,930km (1,199 miles); takeoff speed (reheat) 246km/h (153mph), takeoff run 600m (1,969ft); landing speed 195km/h (121mph); landing run 880m (2,887ft).

MiG-17PFU, SP-6

In autumn 1953 the OKB completed the SP-6, the prototype of an interceptor armed with missiles. The aircraft was basically a MiG-17PF, powered by a VK-1A engine. Under the inner wings were attached four APU-4 launch rails for the K-5 AAM, then in development by Grushin's OKB-2 *Almaz* bureau. This beam-riding missile was matched with the RP-1U *Izumrud* radar, which produced the coded beam locked-on to the target. A single NR-23 was retained, on the right side, and 400lit (880gal) tanks were fitted.

Following successful OKB and State testing, a small series of missile-armed aircraft were produced in 1955 as the MiG-17PFU. These aircraft



MiG-17PFU, SP-6. (OKB)

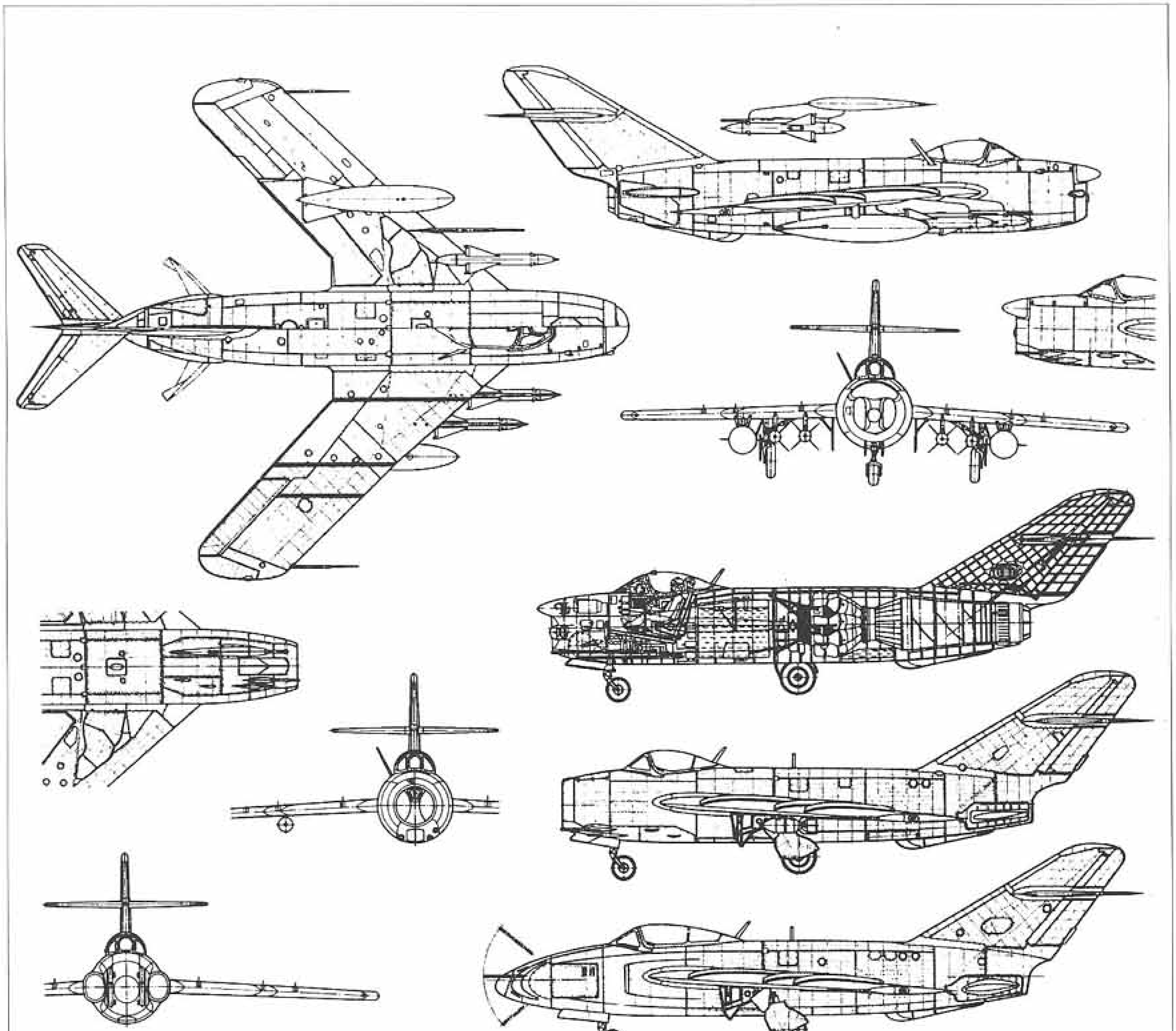
MiG-17PFU, SP-6. (OKB)

differed in being powered by the VK-1F engine and in having no gun armament. The missile was eventually built in series as the RS-1U. The modified APU-4 launcher could equally well take single ARS-190 or ARS-212M rockets. A number of MiG-17PF were modified to PFU standard, and from 1957 all were used as weapon-system trainers for pilots of the MiG-19PM. By this time they were fitted with the improved RS-2US (K-5M) missile, guided by the RP-2U *Izumrud*-2 radar. The ASCC name was 'Fresco-E'.

Dimensions, as MiG-17PF.

Weight empty 4,065kg (8,962lb); internal fuel/oil 1,143kg (2,520lb); weight loaded 5,723kg (12,617lb); maximum weight (with tanks) 6,654kg (14,670lb).

Maximum speed at 4,000m (13,123ft) (MIL power) 1,059km/h (658mph), (maximum reheat) 1,107km/h (688mph); climb to 5,000m/16,404ft (MIL power) 3.3min, (reheat) 2min; climb to 10,000m (32,808ft) (MIL power) 7.9min, (reheat) 4.8min; service ceiling 16,000m (52,493ft); range (at 12,000m [39,370ft] with tanks) 1,850km (1,150 miles); takeoff speed 230km/h (143mph); landing speed 190km/h (118mph).



Top: three views of MiG-17PFU, with inset nose of PF; centre right: cutaway PF; bottom left: three views of MiG-17; bottom right: two views of SN.

SN

In late 1953 the OKB rolled out a unique experimental MiG-17 fitted with a much better scheme of pivoted guns than that of the MiG-15SU. By taking the bull by the horns and completely redesigning the fuselage ahead of Frame 13 it was possible to devote the entire nose to the remarkable SV-25 armament installation devised at the Tula weapon KB of Makarov and Afanas'yev.

This comprised a large frame carried in bearings on a transverse axis and driven by an electric motor and reduction gear to rotate from +27°26′ to –9°48′. On it were mounted three TKB-495 guns, exceptionally light (39kg, 86lb) for their calibre of 23mm, two on the left of the nose and one on the right, with the barrels projecting slightly through large slots. The three box magazines remained stationary. The complete installation weighed 469kg (1,034lb).

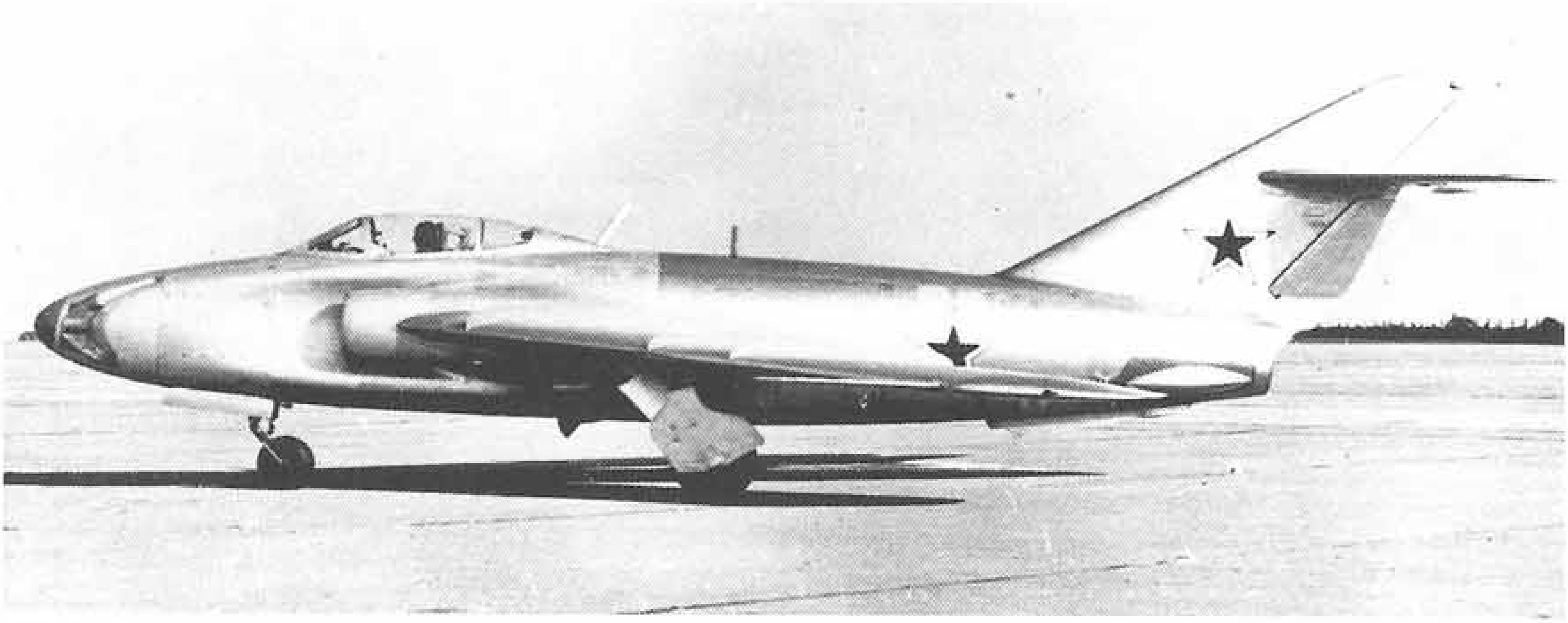
The VK-1A engine was fed by oval inlets on each side immediately ahead of the wing, each inlet dividing into ducts passing above and below the front spar. This required modified wheel-bay doors with curved inner portions forming part of the duct outer skin. To balance the heavy nose the Tank 3 was increased in capacity by 50 litres (11gal). The windscreen and canopy were made slightly wider and longer, giving a better streamlined shape and improved field of view, and the radio antenna was moved to the rear.

Of course, a special sight was needed. The SN was put through factory tests by Georgiy K Mosolov from mid-1953, and then by A Solodovnikov at the NII-VVS from 15 February 1954. It proved a failure, with poor flight performance and useless armament, because, in tight turning combat, firing the guns at any significant elevation threw the aircraft off-target. Mikoyan drew simple sketches to see if elevating guns could be mounted on the fighter's centre of gravity, where recoil would have less effect.

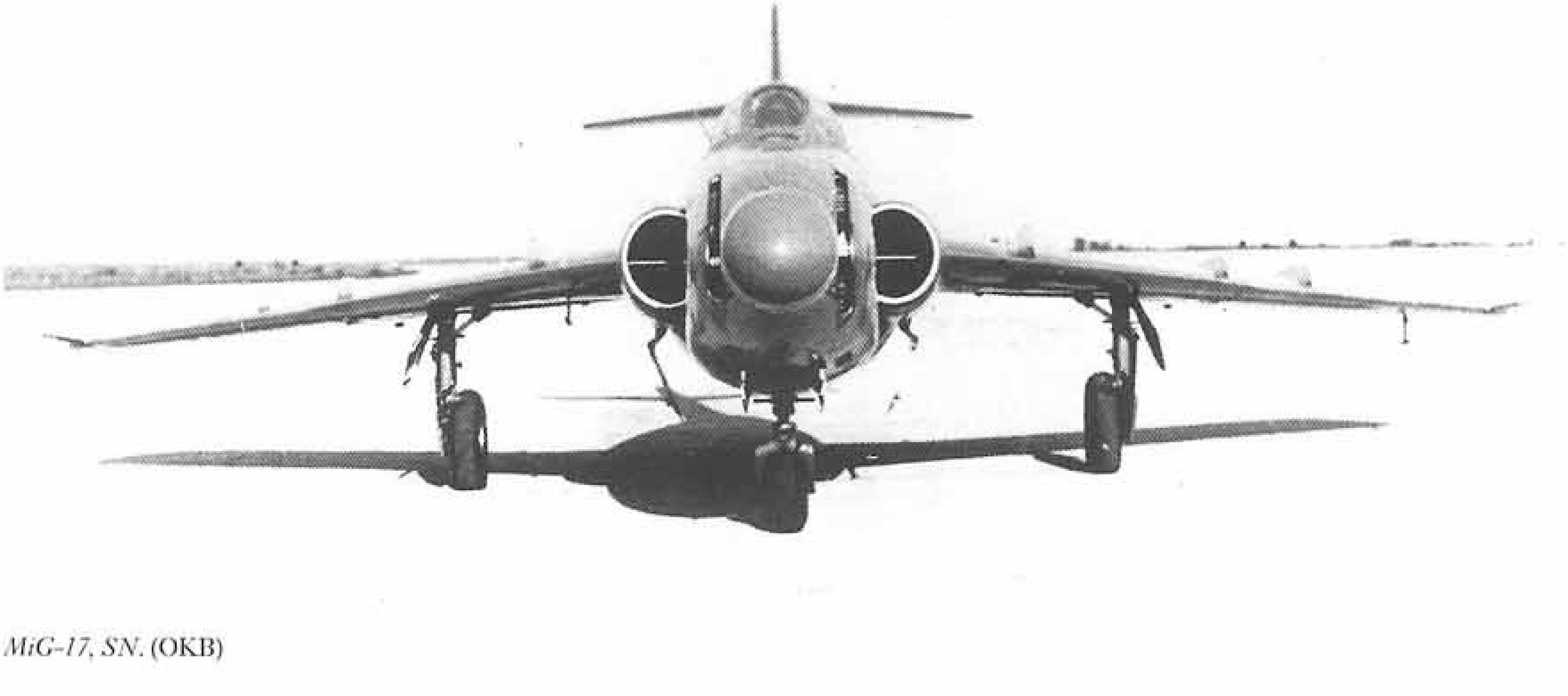
Dimensions unchanged except length 12.333m (40ft 5.5in).

Weight empty 4,152kg (9,153lb); fuel/oil 1,455kg (3,208lb); weight loaded 5,620kg (12,390lb).

Maximum speed 1,047km/h (651mph) at 2,000m (6,561ft), 1,058km/h (657mph) at 5,000m (16,404ft), 1,027km/h (638mph) at 10,000m (32,808ft), 986km/h (613mph) at 12,000m (39,370ft); climb to 5,000m (16,404ft) 2.54min; climb to 10,000m (32,808ft) 6.9min; service ceiling 14,500m (47,572ft). No other data.

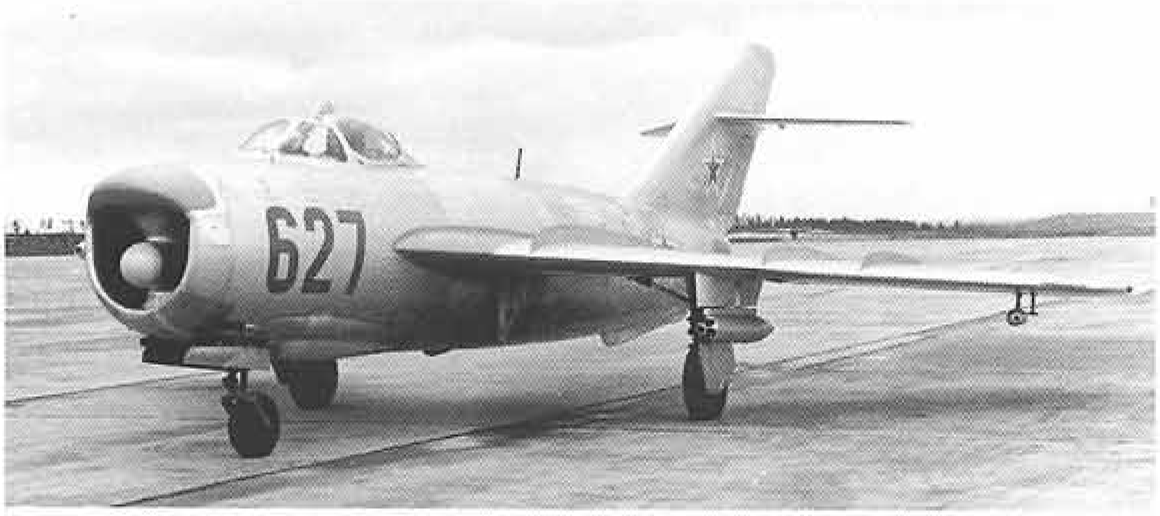


MiG-17, SN. (OKB)

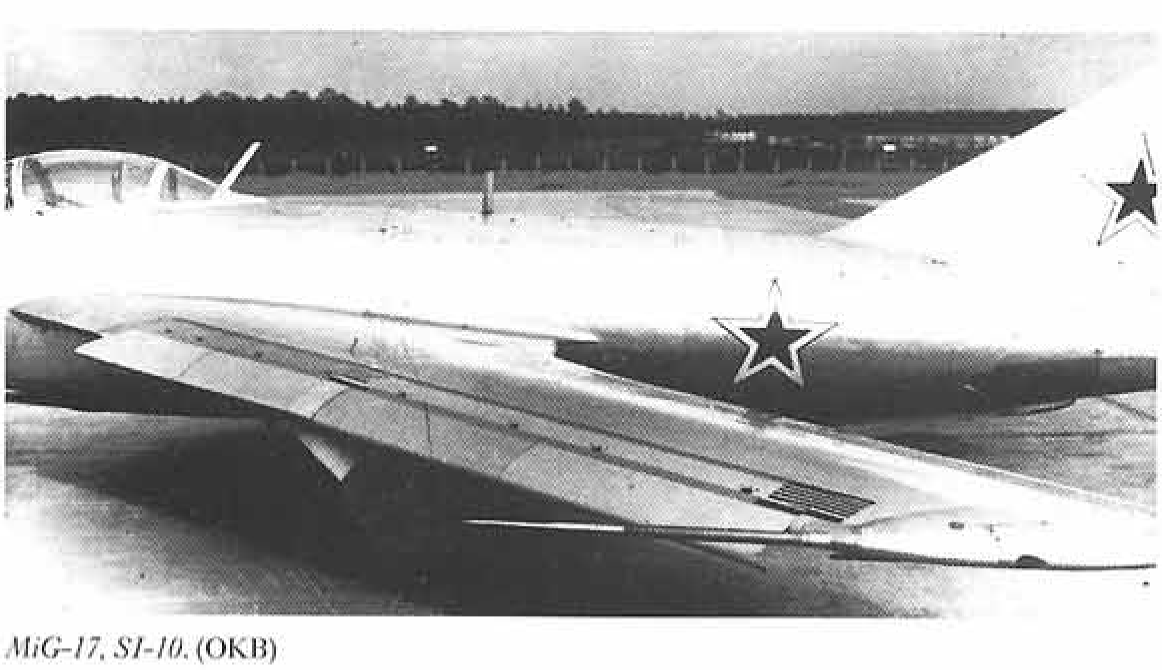


MiG-17, SN. (OKB)

MiG-17, SP-8. (Yefim Gordon archive)


MiG-17PF, SP-10. (OKB)

MiG-17, SI-10. (OKB)


MiG-17, SI-10. (OKB)

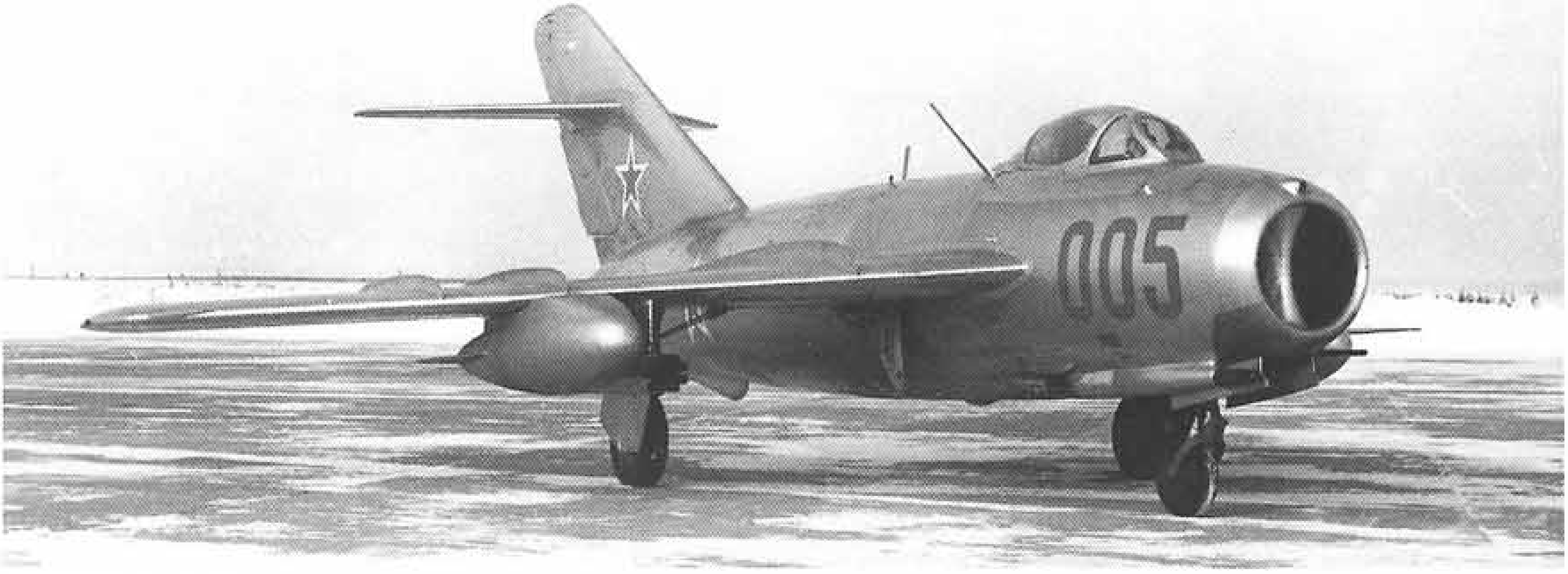
MiG-17 armament testbeds

Several series aircraft were used in 1954–55 to test new armament. The SP-8 was the principal testbed for the SRD-3 *Grad* (hail) radar-ranger housed in the top of the nose. This was tested with the *Sneg* (snow) head-up display, but this was abandoned. The production sight was the ASP-4NM matched with the *Kvant* (quantum) radar ranger, which was retrofitted to many MiG-17s. The SP-9 was an interceptor testbed fitted with RP-2U *Izumrud-2* radar and long APU rails for RS-2U (K-5M) guided missiles in place of guns. Missiles were launched automatically by a ZP-6S link sensing the target's range and radar lock-on. The SP-10 was MiG-17PF, callsign '627', with VK-1F engine and RP-5 *Izumrud* radar, which in 1955 was used to test a new gun with a very high rate of fire. The demountable gun tray was redesigned, the original weapons being replaced by two new 23mm guns with two superimposed barrels each apparently fed by a curious rotary eight-tube magazine. No details of the gun have been discovered. Wing pylons carried seven-tube launchers for ARS-57 rockets, presumably for air-to-air use as interceptors are not normally used for ground attack.

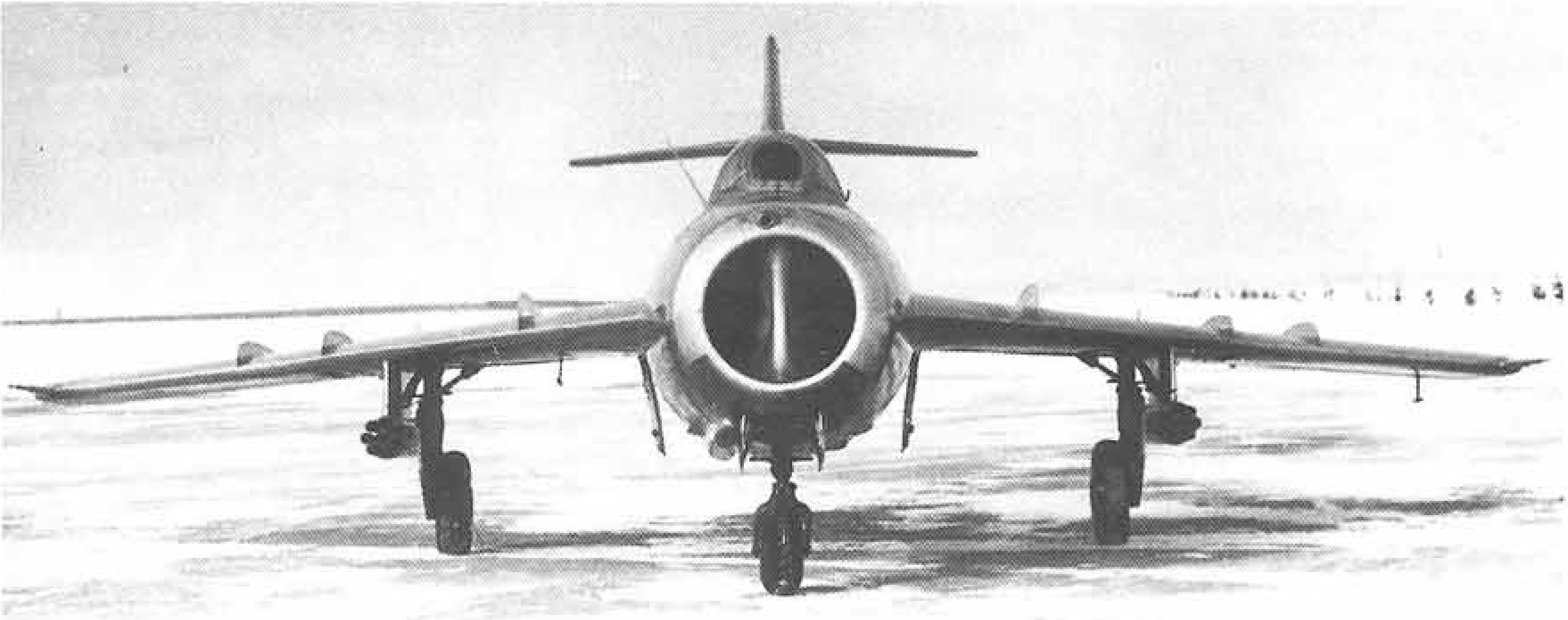
The SI-16, callsign '005', was fitted with a Nudel'man N-57 gun of 57mm calibre, replacing the N-37D on the right side. This huge gun fired 2.78kg projectiles at a cyclic rate of 180–230/min with muzzle velocity 980m (3,215ft)/sec. The SI-19, callsign '104', was fitted with totally new (modified APU-4) pylons projecting far ahead of the leading edge of the inboard wing. These carried tubes for single TRS-190 rockets. Both aircraft were tested at the NII-VVS by Solodovnikov.

SI-10

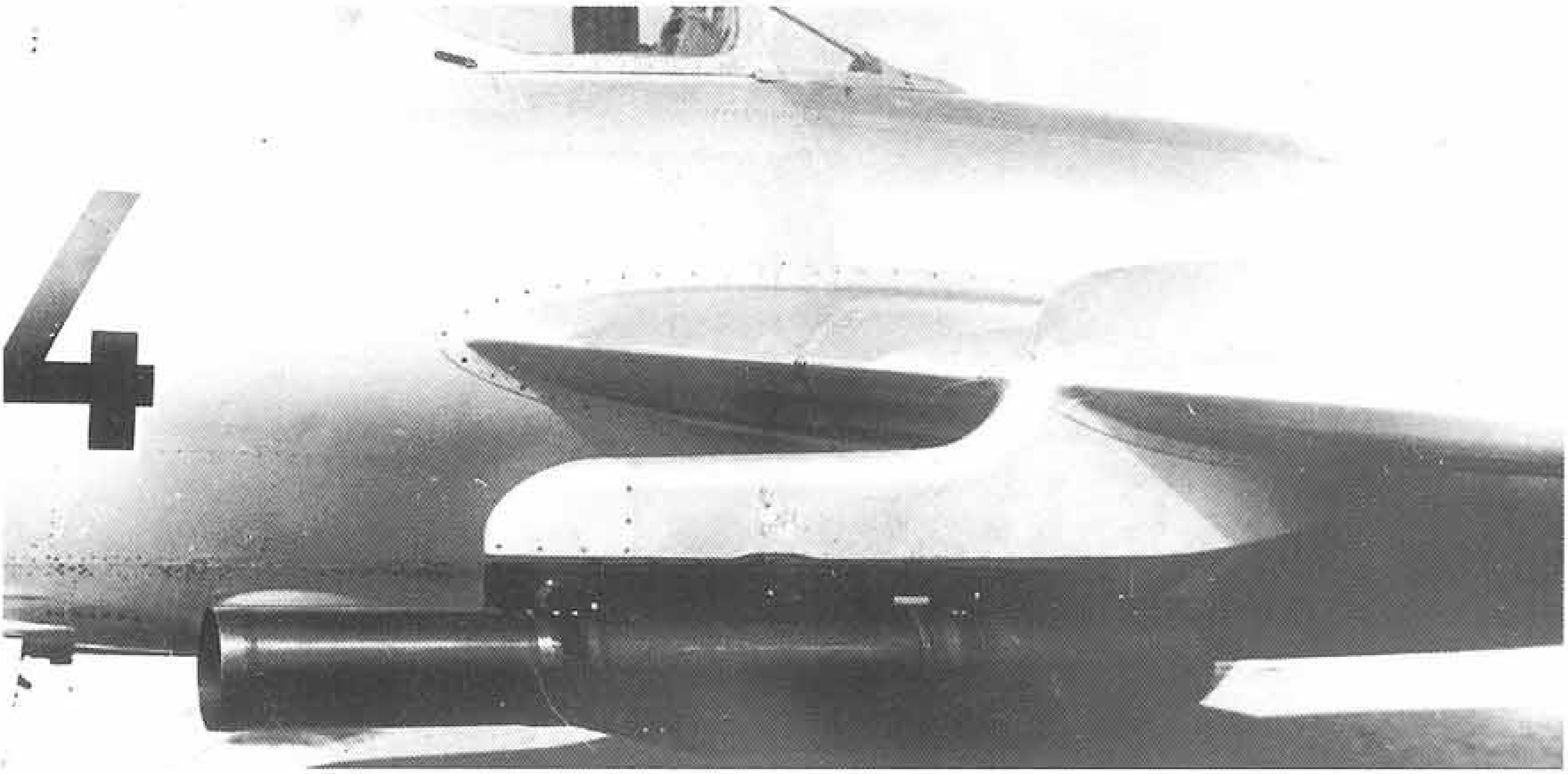
Having studied the slats and 'all-flying' tail of the F-86E Sabre, in 1954 the OKB modified MiG-17 callsign '214' (VK-1A engine) to enhance its flying qualities. The new flaps were pure Fowler, running aft on three tracks to 16° for takeoff and 25° for landing to give a major addition to the wing area. Along 76 per cent of each leading edge were fitted automatic slats travelling out on seven tracks. The fences were removed. Under the outer wings, ahead of the ailerons, were fitted interceptors (spoilers) which flicked open



MiG-17, SI-16. (OKB)



MiG-17, SI-16. (OKB)



MiG-17, SI-19. (OKB)

whenever the adjacent aileron deflected more than 6° (presumably upwards or downwards). It was almost identical to that previously used on the I-320 prototypes. The final modification was to fit a fully powered 'all-flying' tailplane, the elevators adding camber. Tailplane limits were +3°/–5°.

Sedov began factory tests on 27 November 1954. Many other pilots flew No. 214 both at the OKB and NII-VVS. Surprisingly, field length was not improved, but it was universally agreed that the new horizontal tail was a great success.

Dimensions unchanged.

Weight empty increased from 3,940kg (8,686lb) to 4,140kg (9,127lb); internal fuel 1,128kg (2,487lb); weight loaded 5,490kg (12,103lb).

Maximum speed 1,060km/h (659mph) at sea level, 1,114km/h (692mph) at 2,000m (6,561ft); service ceiling 15,600m (51,181ft); takeoff speed 232km/h (144mph), takeoff run 500m (1,640ft); landing speed 194km/h (120.5mph); landing run 1,095m (3,593ft), significantly longer than a regular MiG-17F.

Other MiG-17 testbeds

One of the most important test aircraft was used to develop an irreversible fully powered flight control system. Based at the LII-MAP in 1954, it was designated the MiG-17NBU. Where the record is confusing is that similar work was done with the MiG-17GU. It is not known whether these were two designations for the same aircraft. In the same way, the designations MiG-17M and MiG-17MM (improved M) may both apply to the same aircraft. The MiG-17M was a conversion of a series fighter in VVS workshops to serve as a testbed for pilotless targets. The MiG-17MM was also a target, with radio control from a distant pilot.

The SDK-5 was a MiG-17 which complemented the MiG-9L in helping to develop the guidance system for the KS-1 *Komet* cruise missile. Like the earlier testbed it had a forward-facing antenna above the inlet and an aft-facing antenna above the tail. Again like the MiG-9L, it later participated in the development of the huge Kh-20. *See* 'Guided Missiles' for details of both.

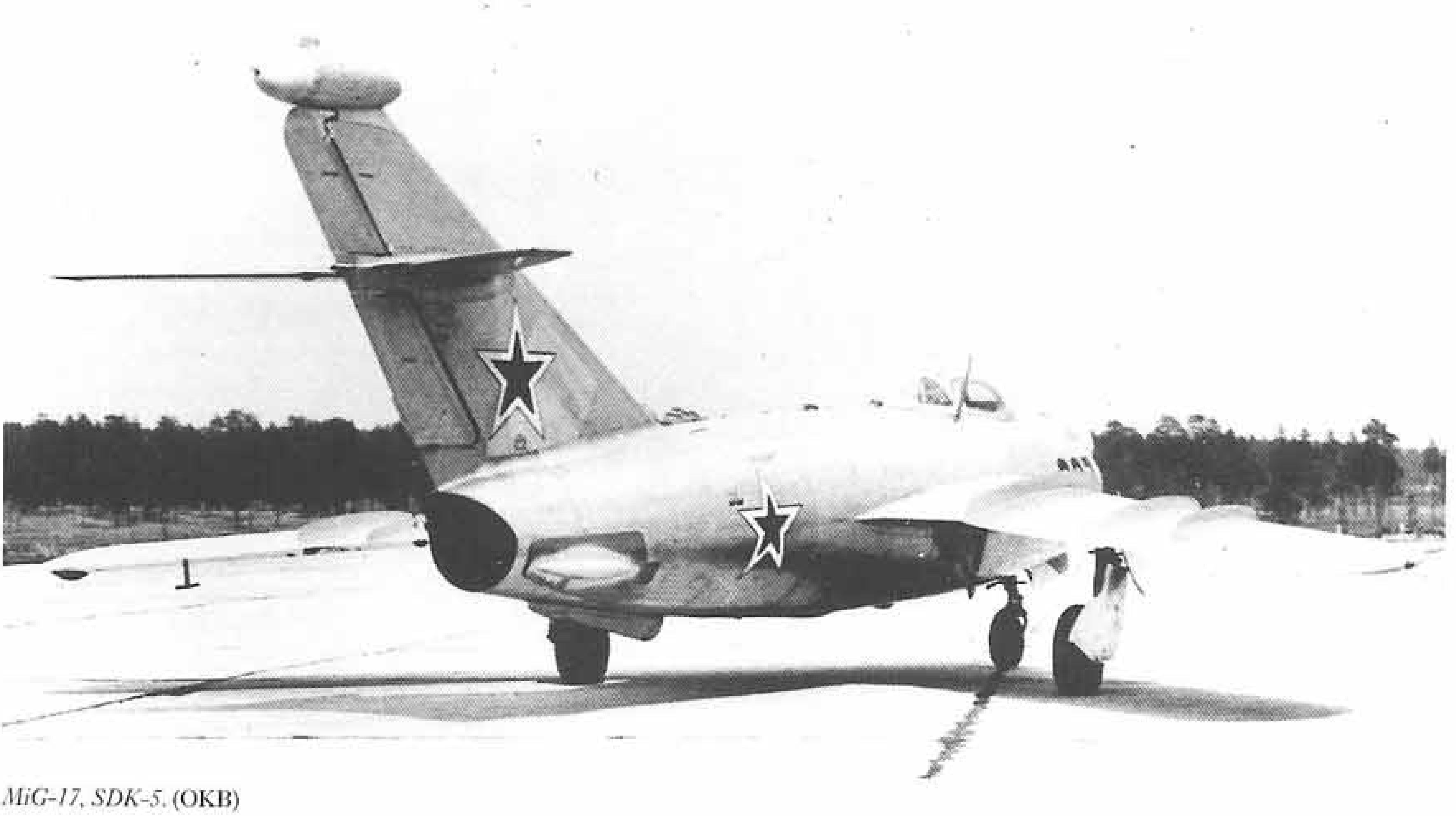
I-340, SM-1

It had always been understood that the Soviet developments of the Rolls-Royce Nene were stop-gap expedients, adopted only until home-designed engines could take over. In early 1950 the engine KB of Aleksandr A Mikulin first ran the AM-5 axial turbojet, designed by Sergei K Tumanskiy. This was initially cleared for flight at a thrust of 1,900kg (4,189lb). It was notable in having a diameter of only 670mm (26.4in), roughly half that of a VK-1, and it clearly had the potential of improved fuel economy.

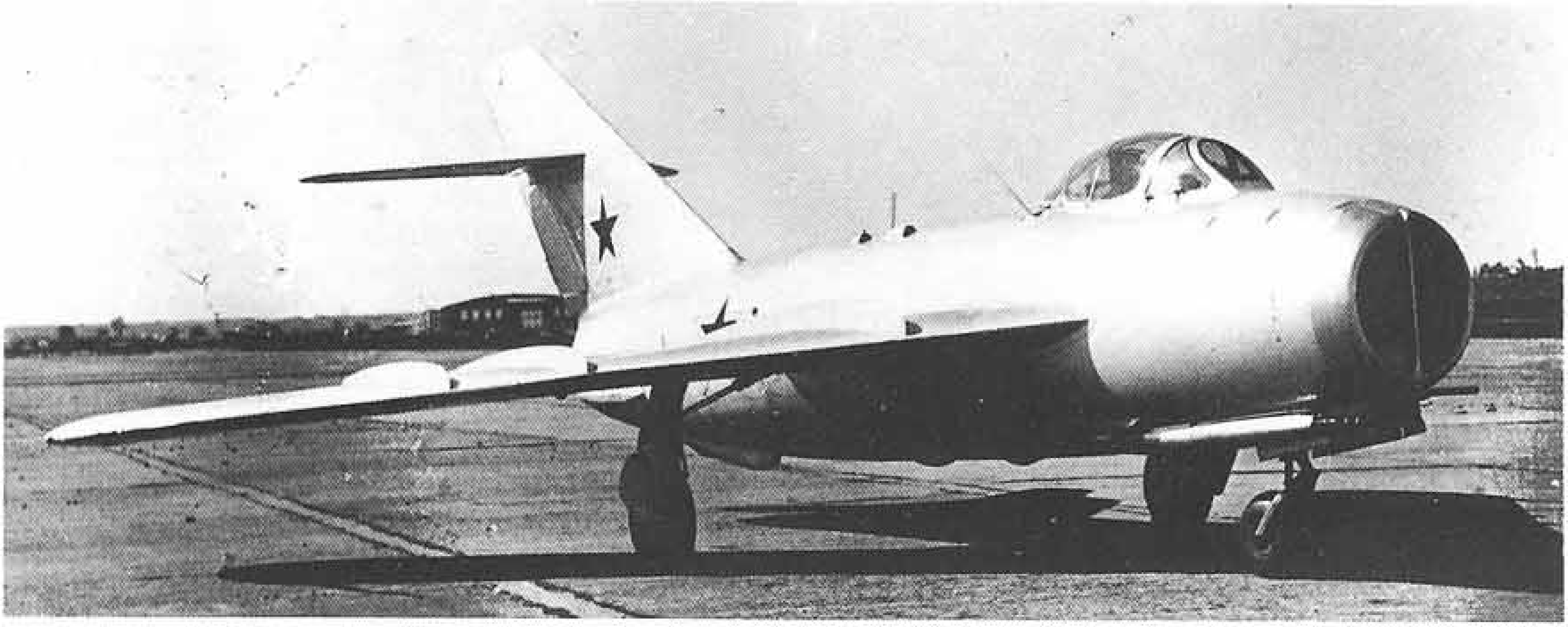
Mikoyan became excited at the prospect of replacing the supposedly obsolescent centrifugal-compressor engines by a twin installation of the AM-5. He was one of the designers summoned to the Kremlin on 30 July 1950 to discuss future fighters. The AM-5 was seen as the key to two new twin-engined fighters offering unprecedented range and if possible supersonic performance. Yakovlev was assigned a radar-equipped interceptor. Mikoyan was assigned an agile long-range escort, able to cruise with one engine shut down (this led to the MiG-19).

On 20 April 1951 work began converting the original 'MiG-15bis-45°', the SI-2 prototype of the MiG-17, as a testbed for twin AM-5A engines, each rated at 2,000kg (4,409lb). The modification took seven months, because the entire length of the inlet ducts had to be enlarged and the fuel system redesigned. The rear fuselage was much wider to accept the new engines side by side. The new large airbrakes were modified, and a 15sq m (161.5sq ft) braking parachute was added in a box under the rear fuselage, where there was also a ventral strake. OKB records state that the slimmer engines allowed Tank 3 to be replaced by three rear-fuselage cells totalling 770 litres (169gal).

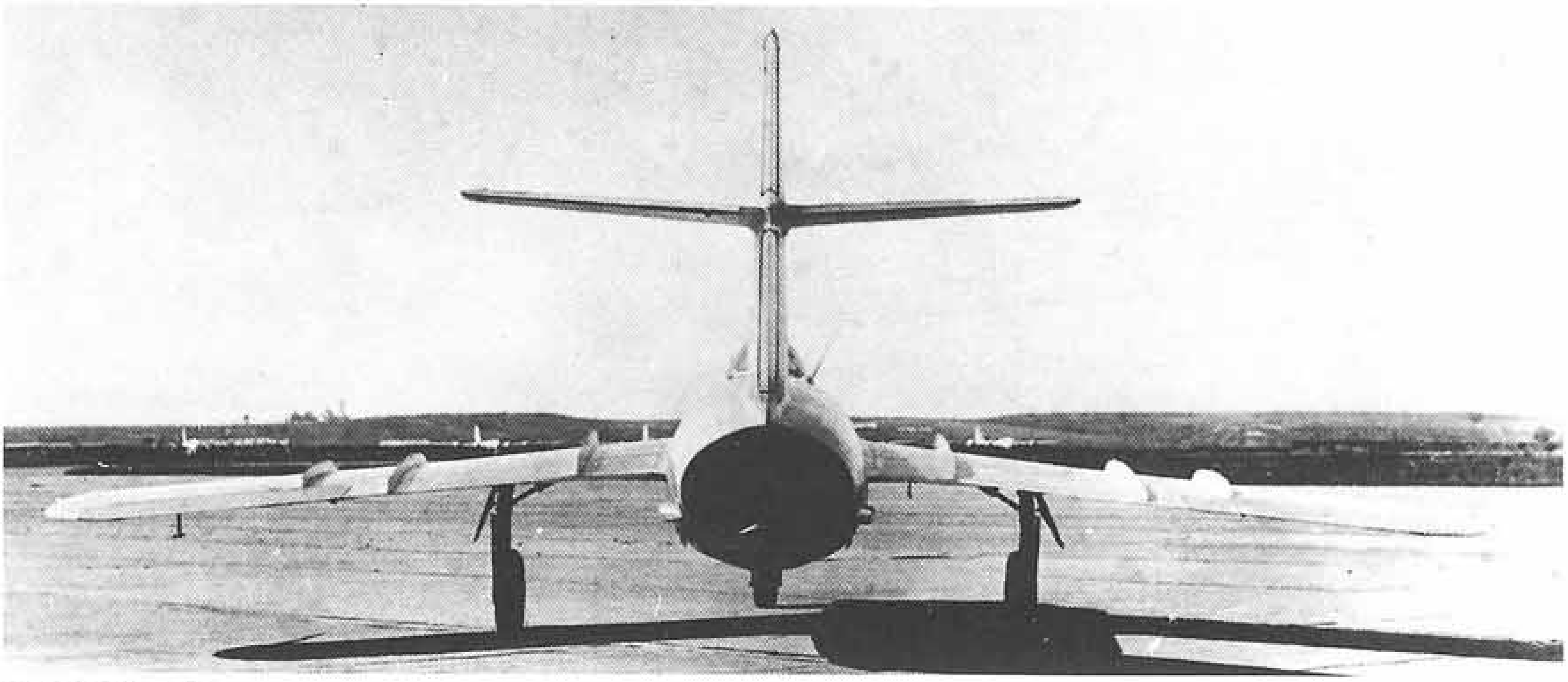
Sedov made the first flight in December 1951. Thrust was insufficient to make the SM-1 supersonic.



MiG-17, SDK-5. (OKB)



I-340, SM-1. (OKB)



I-340, SM-1. (OKB)

Dimensions unchanged.

Weight empty 3,705kg (8,168lb); internal fuel 1,256kg (2,769lb); weight loaded 5,210kg (11,486lb).

Maximum speed 1,193km/h (741mph) at 1,000m (3,280ft), 1,154km/h (717mph, Mach 0.997) at 5,000m (16,404ft); climb to 1,000m 0.16min, to 5,000m 0.94min, to 10,000m (32,808ft) 2.85min, to 15,000m (49,213ft) 6.1min; service ceiling 15,600m (51,181ft); range at 10,000m 1,475km (917 miles); takeoff run 335m (1,099ft); landing run 568m (1,864ft).

Foreign MiG-17s

Polish

The MiG-17 served in Poland long after later MiG generations had taken over in other countries. This was mainly because the Polish aircraft industry developed indigenous versions, but also because the MiG-17 was used by the PWL (Polish Air Force) primarily as a close-support aircraft.

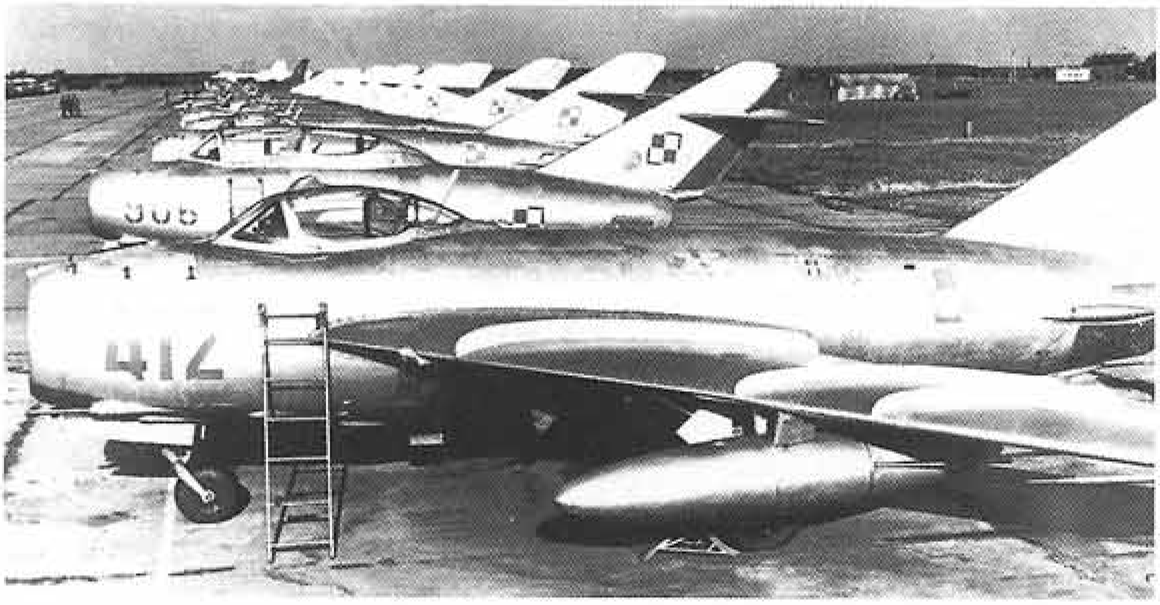
Lim-5

Poland used MiG-17s from 1955. A year later the decision was taken to produce the MiG-17F under licence at WSK-PZL Mielec as the Lim-5 and its VK-1F engine at WSK-PZL Rzeszów as the Lis-5. Following tests with No. 00-01 and No. 02-01 a total of 222 Lim-5s were produced between April 1957 and 1960. The air force saw it as a close-support aircraft, and modifications were directed towards improving its ability to use short unpaved airstrips.

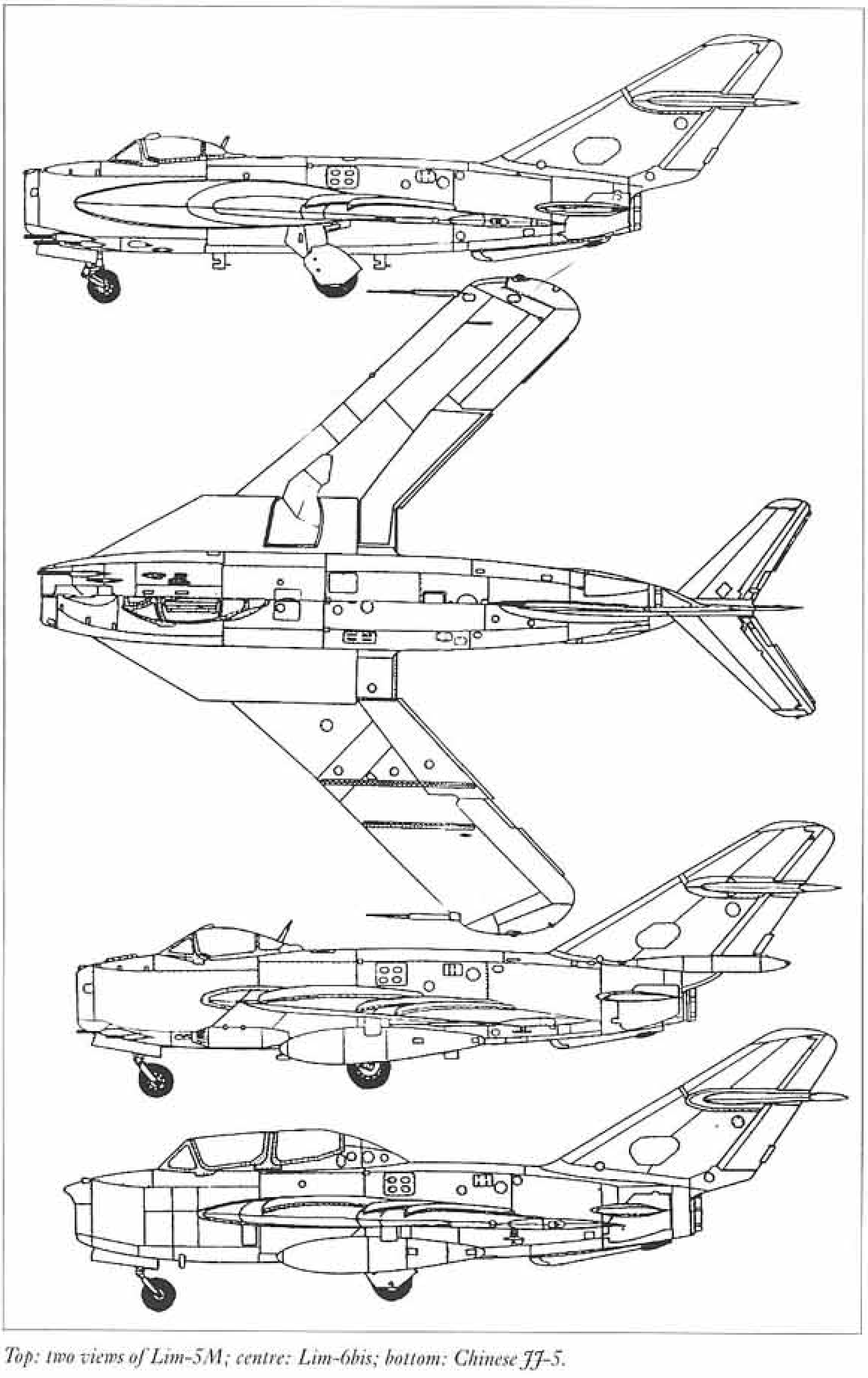
In 1958 a team at Mielec led by Ing Felix Borodzik developed the CM-I version with improved STOL performance. Features included a Type SR assisted-takeoff rocket of 1,000kg (2,204lb) thrust and a Type SH-19 parabrake of 12sq m (129sq ft) area streamed from a box under the rear fuselage.

Lim-5M

In parallel the Mielec plant developed a more radical modification, designated CM-II, specifically for operations from unpaved runways. This was fitted with a new main landing gear, each unit with modified shock struts joined to the centre of an axle carrying two wheels, one on each side of the leg, with antiskid brakes and 660 × 160mm low-pressure tyres. To maintain the thickness/chord ratio, the greater depth of the retracted landing gear was accommodated by extending the inboard wing forwards with a large



Lim-5. (Yefim Gordon archive)



Top: two views of Lim-5M; centre: Lim-6bis; bottom: Chinese JJ-5.

glassfibre fairing which also accommodated fuel. To balance this extra forward weight the rear-fuselage tanks were also enlarged. The racks under the outer wings carried weapons only and were no longer plumbed for fuel. The junction between the enlarged inner wing and the original surface was abrupt, incorporating a large fence.

These features were tested in 1960 on CM-II prototypes No. 10-30 and No. 16-01. Mielec built a total of sixty series aircraft, designated Lim-5M. They were not popular because at high speeds airflow separation around the enlarged wing roots gave tail buffeting and poor handling. Later all surviving aircraft were rebuilt as Lim-6bis.

Dimensions unchanged, except wing area 23.71sq m (255.2sq ft).

Weight empty 4,473kg (9,861lb); internal fuel 1,550kg (3,417lb); weight loaded (normal) 6,256kg (13,792lb), (maximum) 6,954kg (15,331lb).

Maximum speed 1,108km/h (688.5mph) at 3,000m (9,842ft); climb to 5,000m (16,404ft) 3.62min, to 10,000m (32,808ft) 6.93min; service ceiling (MIL. power) 13,250m (43,471ft), (maximum reheat) 15,200m (49,869ft). No other data.

Lim-5P

The Mielec factory was licensed to produce the MiG-17PF, with no modifications. The first Lim-5P began its acceptance flight programme on 18 February 1959, and the last of 129 series aircraft, Product ID No. 06-41, flew on 29 November 1960.

Lim-5MR

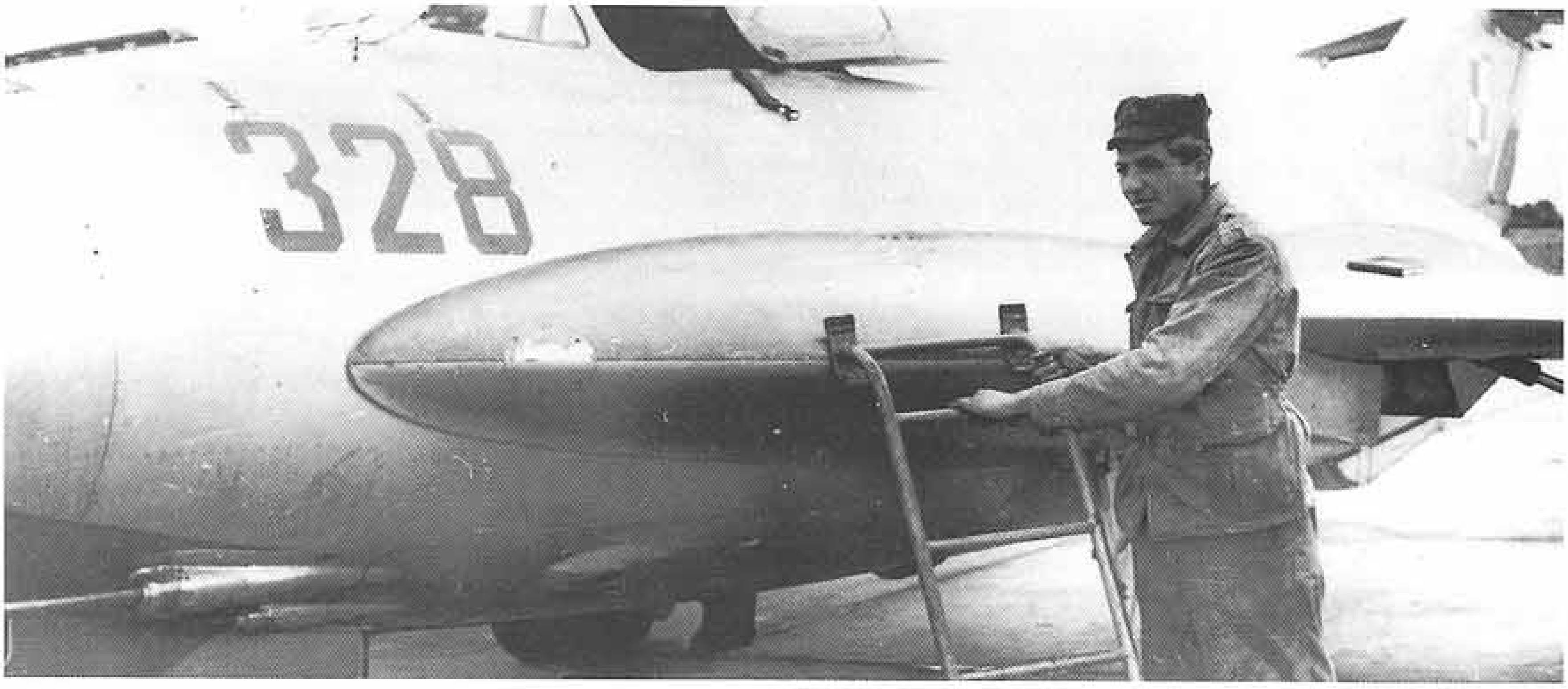
Unbuilt project of 1960 with span increased to 10.58m by tip pods housing cameras: AFA-39, AFA-BA/40R, AFA-BAF/21S and/or AFP-21.

Lim-6

In 1961 prototype No. 16-01 was tested with blown flaps (designation in Russian, SPS) and a ribbon-type parabrake in a tubular container under the rudder. The engine incorporated a bleed manifold and other changes and was redesignated Lis-6. A total of forty aircraft were built to this specification, but did not enter service because the blown flaps caused engine compressor stalls and flameouts.

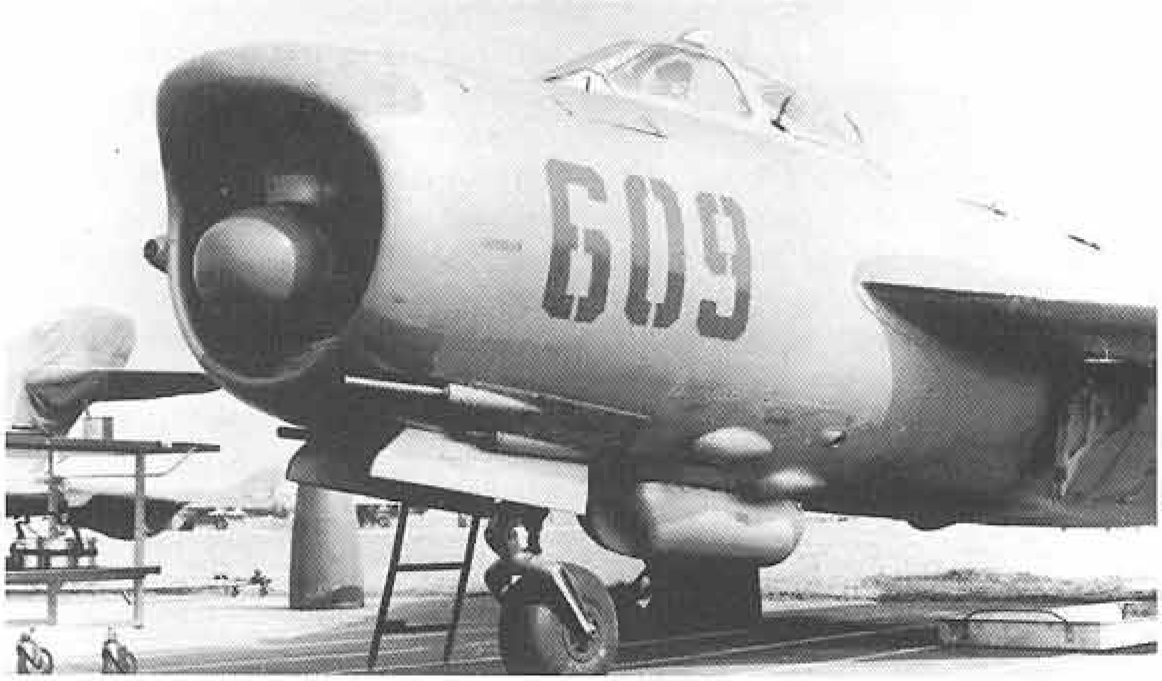
Lim-6R

From December 1962 a prototype was tested of this reconnaissance version with an AFA-39 camera in a CMR-



Inboard wing of Lim-5M. (Yefim Gordon archive)

Lim-6. (Yefim Gordon archive)



Lim-6R No. 100609. (Yefim Gordon archive)

9320-00 pod based on the Mars-2 rocket launcher. This was scabbed on under the fuselage.

Lim-6bis

With this the big inboard wing and twin-wheel main landing gear were finally abandoned. Features included the SH-19 parabrake under the rudder, provision for an SR-1500-00 assisted-takeoff rocket of 1,200kg (2,646lb) thrust, and two new pylons ahead of the leading edge only 0.525m (20.7in) from the centreline. These normally carried Mars-2 rocket launchers (16 S-5 rockets of 57mm calibre). Loads could comprise four Mars-2 or two Mars-2 and two 400lit tanks.

A total of seventy aircraft were built to this design, the last being rolled out in February 1964. In addition all surviving Lim-5M and Lim-6 aircraft were remanufactured to this standard. The front-line force of some 170 Lim-6bis had a long life, about half remaining in service to 1990. Data are for series test aircraft No. 05–04, tested 15 April to 24 June 1964.

Dimensions as MiG-17F.

Weight empty 4,335kg (9,557lb); internal fuel 1,130kg (2,491lb); weight loaded (clean) 5,550kg (12,235lb), (two launchers and two tanks) 6,500kg (14,330lb).

Maximum speed (with four external stores) 1,019km/h (633mph) at 3,000m; climb to 5,000m 4.0min, to 10,000m 8.3min. No other data.

Lim-6bis. (Yefim Gordon archive)

Lim-6M

With this designation, all surviving Lim-5P interceptors were rebuilt from 1971 as ground-attack aircraft. Radars were removed (external appearance being little changed) and the parabrake, assisted takeoff rocket and inboard pylons were the same as those of the Lim-6bis. The three NR-23 guns were retained.

Lim-6MR

A few Lim-5P were converted into these reconnaissance aircraft, with Lim-6bis features.

Chinese

The People's Republic of China signed a licence to build the MiG-17F on 8 April 1955, with the Chinese designation J-5. No significant modifications were requested, and tooling was rapidly put in place at the aircraft factory at Shenyang (previously called Mukden). The first prototype was rolled out on 13 July 1956, and was successfully flown by a Soviet test pilot on 2 August of that year.

Initially the engines, radio and most instruments were imported, but Chinese industry gradually acquired further licences to cover most of these items. The engine, a true Chinese copy, went into production in late 1956 at the Shenyang engine plant (later called Liming Engine Factory), with the designation WP5.

In May 1961 the Soviet Union supplied documentation for licence manufacture of the MiG-17PF. This went into production at the Chengdu factory as the J-5A, with export versions designated F-5A. Major parts, including radars, were supplied in September 1962, and the first Chinese interceptor flew on 11 November 1964.

By this time the Chinese had decided to produce their own dual trainer version, designated JJ-5, export versions being designated FT-5. This required substantial design effort, though the tandem canopies were based on the MiG-15UTI, which was used in China as the JJ-2. The nose incorporated provision for the *Izumrud* radar, and a proportion were flown by an instructor pilot and a trainee radar backseater. Under the right side was a single NR-23 gun, and the S-13 camera was on the right side of the nose. The wings were plumbed for 400lit (880 gal) tanks, and bombs up to 250kg (551lb) could be carried instead.

The first JJ-5 was flown at Chengdu on 8 May 1966. Substantial export sales were gained for both the fighter and trainer. Total Chinese production amounted to 767 single-seat versions and 1,061 trainers. Data for JJ-5.

Dimensions as MiG-17PF.

Weight empty 4,080kg (8,995lb); normal loaded 5,400kg (11,905lb); maximum loaded 6,332kg (13,959lb).

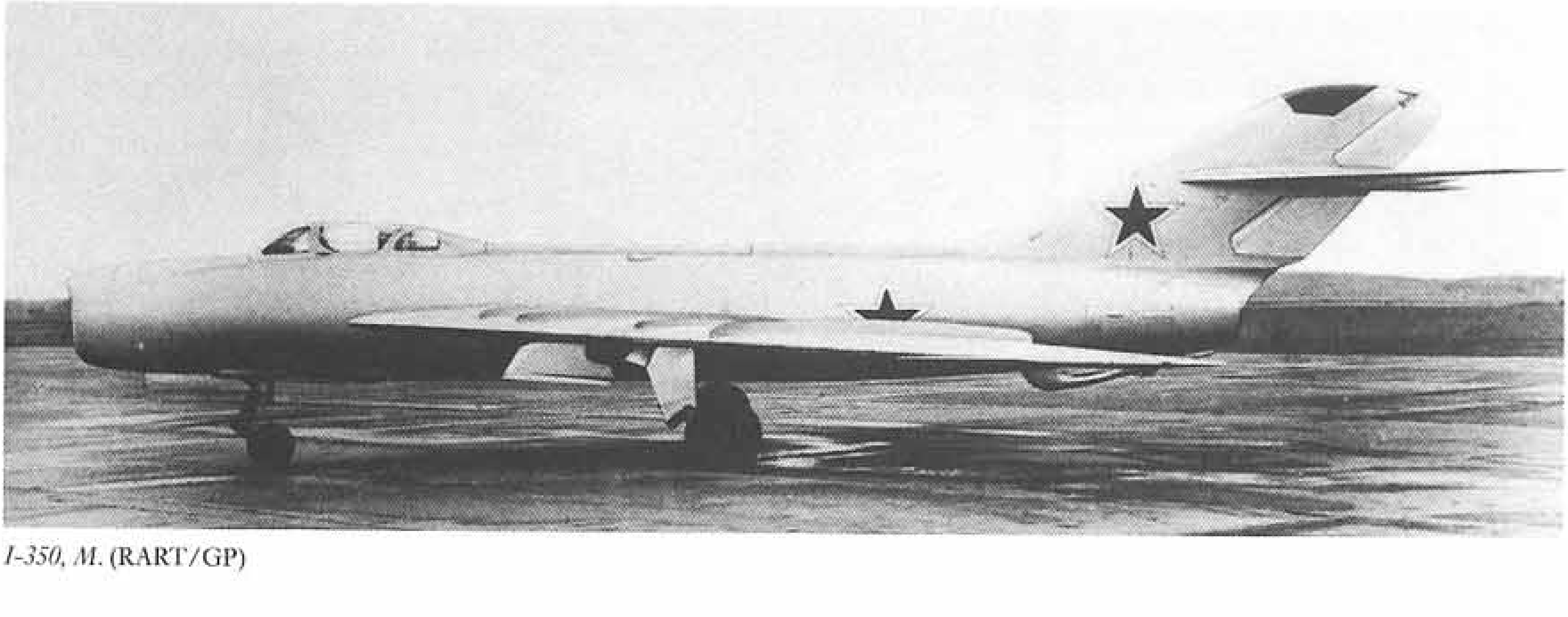
Maximum speed 902km/h (560mph).

I-350, M

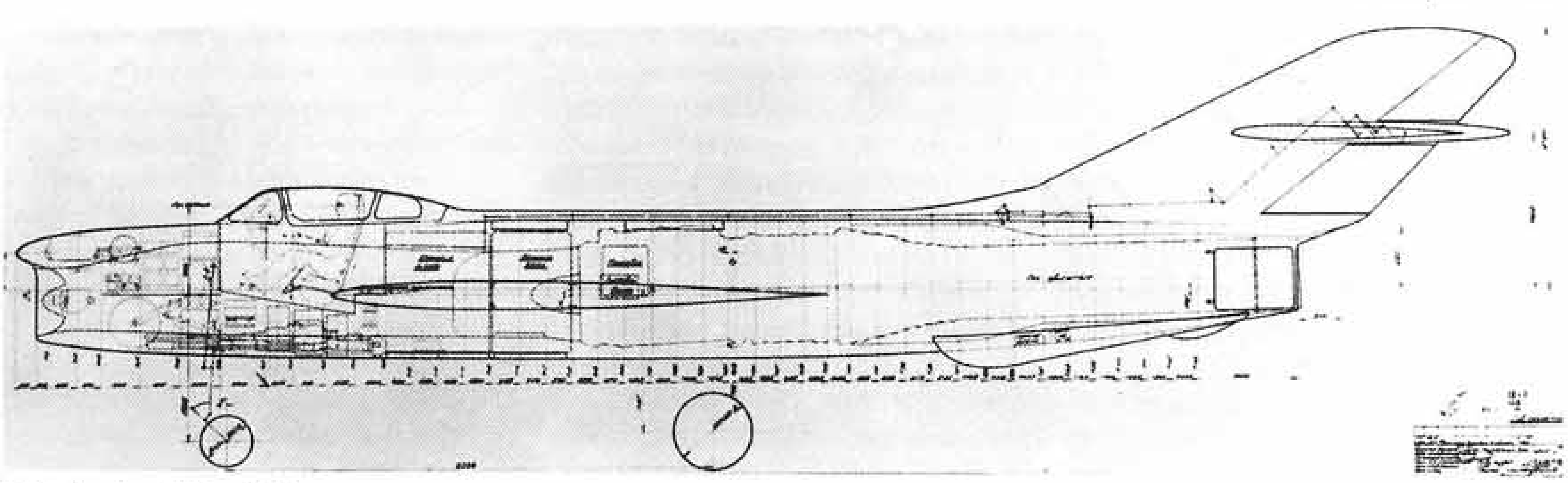
As noted earlier, even though they were made in vast numbers, the Klimov derivatives of the British Nene turbojet were regarded merely as temporarily useful until Soviet design teams could develop powerful axial engines. The pioneer of such engines was Arkhip M Lyul'ka. He designed from 1936, began prototype construction in beleaguered Leningrad (now St Petersburg) in 1941, and ran his first engine in 1943. In late 1946 he began to design the much more powerful TR-3, which first ran in 1949. On 10 June 1950 the Council of Ministers ordered the MiG OKB to use this engine to design a true supersonic fighter.

The resulting aircraft was called M in the design bureau, and it received the industry designation I-350. Project manager was leading engineer A V Minayev. As far as possible he retained established principles, such as the use of a nose inlet with the ducts divided past the cockpit, port and starboard wings attached on each side at midlevel to strong fuselage ring frames, and a horizontal tail mounted high up on the fin. The forward fuselage was similar to that of the MiG-17P, with identical provision for *Izumrud* radar. Armament was to be either the same as on the MiG-17 (one N-37D and two NR-23), as shown in the sectioned side elevation, or two N-37D as shown in the three-view drawing.

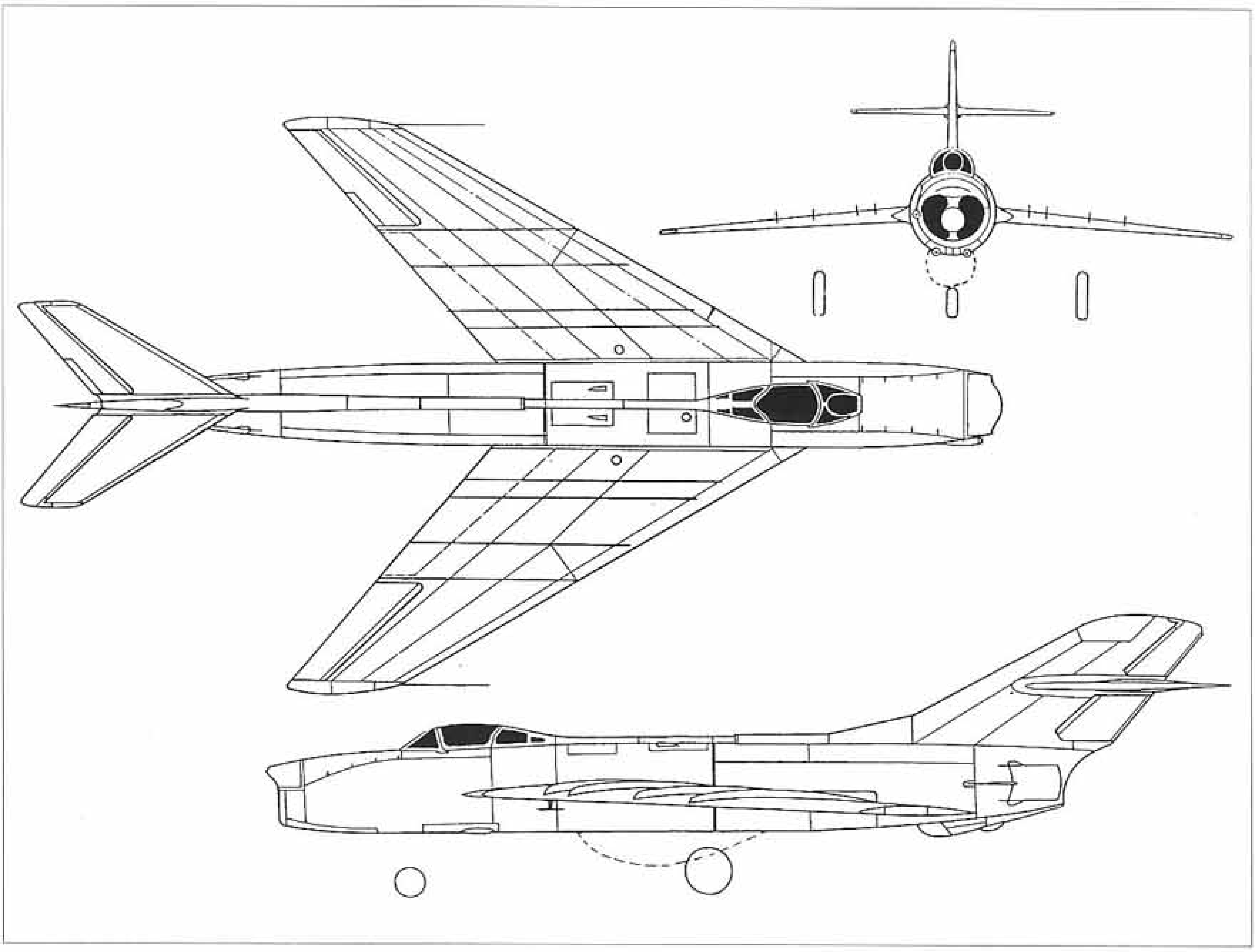
It was planned eventually to use the TR-3F with an afterburner, and as this engine was to be 8.1m (26.5ft) long the fuselage had to be greatly lengthened. Another innovation was a completely new design of wing. This was aerodynamically schemed by CAHI, which alone had a background of supersonic research, their team leaders being Georgiy S Byushgens and Vladimir V Struminskiy. They used CAHI profile S-12s at the root, reducing to SR-7s at the tip, with the impressive sweep angle of 57° along the ¼-chord line, giving a leading-edge sweep of 60°. The wings were set at a static anhedral angle of –4°. To prevent the feared outward flow of the streamlines towards the tips no fewer than four fences were used on the upper surface



I-350, M. (RART/GP)



OKB drawing of Aircraft M.



I-350, M.

of each wing. The leading edge was fixed, and on the trailing edge were Fowler flaps and conventional boosted ailerons. Structurally the wings had tapered stretch-levelled skins, and a main spar kinked to leave room inboard for the main landing gear.

This wing was a remarkable accomplishment for 1950. It showed that a thin wing could be made torsionally stiff enough for powerful outboard ailerons not to give rise at supersonic speeds to reversal of lateral control. (Three years later the F-100 emerged with no flaps because the North American Aviation designers failed to solve this problem.) Derivatives of this wing were later to be seen on the MiG-19 and many MiG prototypes.

Fuel was housed in two fuselage and two wing tanks. The rear fuselage could be disconnected at Frame 24 for access to the engine. Beneath it was a ventral strake/bumper (the OKB side elevation shows two), incorporating a box with twin doors for a parabrake, the first time the OKB had included one. The twin airbrakes were almost rectangular and mounted on each side of the extreme rear fuselage.

The tail resembled an enlarged version of that of the MiG-17, with a fixed tailplane of 3.46m (11ft 4¼in) span, with a leading-edge sweep of 55°. As the side elevation shows, the push/pull rod controls to the elevators and the upper and lower rudders were mounted above the fuselage inside a spine, which was another 'first' for the OKB. At midlength this spine incorporated an engine-bay cooling-air inlet. Yet another was to use vhf radio able to use an antenna inside a flush dielectric fairing forming the top of the fin.

The canopy slid aft on two rails. The landing gear was similar to that of the MiG-17 but strengthened, and with the track considerably extended to 4.47m (14ft 8in) and the wheelbase to no less than 4.997m (16ft 4¾in). There were longer trailing levers on the main units, which had different doors, comprising a large one mounted obliquely on the leg and a single door hinged under the wing root to cover the entire wheel bay. The nose unit retracted forwards, shortening to fit in a bay between the air ducts and closed by two doors. There is no record of wing pylons, but provision was made for a single tank of 800 litres (176gal) to be scabbed under the fuselage, as an alternative to a large bomb (possibly of 1,000kg).

Only a single M prototype was built, powered by a TR-3A turbojet without afterburner, rated at 4,600kg (10,141lb) thrust. Sedov began the flight-test programme on 16 June 1951. There are grounds for considering this to be the first fully developed supersonic fighter in the world to fly, though the same could not be said of the engine. After briefly exploring handling, Sedov returned to Zhukovskiy and reduced power. The engine flamed out, and as it spooled down all hydraulic boost was lost. Sedov managed to control the aircraft manually, but the right main leg did not extend and Sedov blew it down by the pneumatic emergency system just as the aircraft hit the runway.

Five further flights were curtailed by engine problems, and the programme was abandoned, because twin AM-5 engines showed the promise of better maturity. Never-built derivatives were the I-350 (M-2) with *Korshun* radar, with a dish antenna centred in the inlet, and the MT tandem-seat trainer (drawings of which appear in Gunston's *Encyclopedia of Russian Aircraft*). The graceful I-350 was unknown in the West, and so it did not receive an ASCC name.

Span 9.73m (31ft 11in); length 16.652m (54ft 7⅝in); fuselage length (excluding radar lip) 13.192m (43ft 3⅜in); wing area (OKB figure probably approximate) 36sq m (387.5sq ft).

Weight empty 6,125kg (13,503lb); loaded weight (normal) 8,000kg (17,637lb), (maximum) 8,710kg (19,202lb).

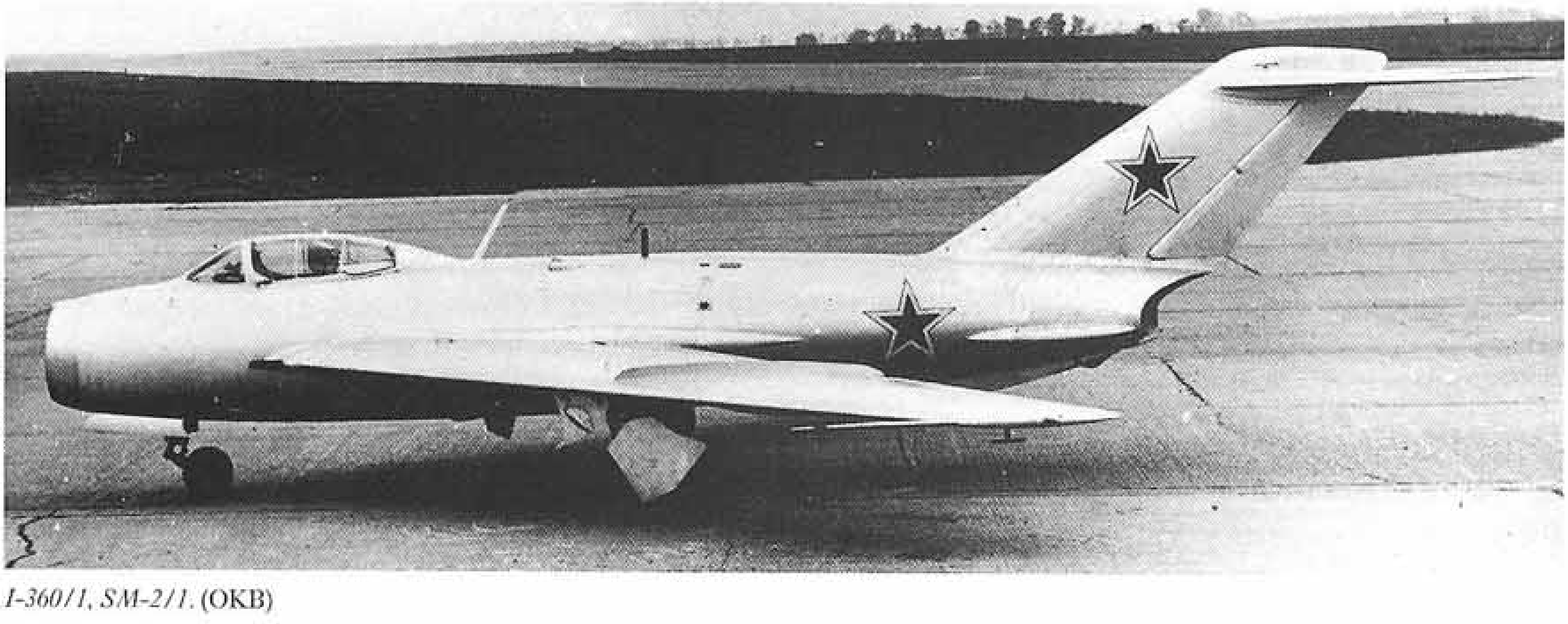
Maximum speed 1,240km/h (770.5mph, Mach 1.01) at sea level, 1,266km/h (787mph, M1.19) at 10,000 (32,808ft); climb to 5,000m (16,404ft) 1.1min, to 10,000m (32,808ft) 2.6min; service ceiling 16,600m (54,462ft); range 1,120km (696 miles) (if ventral tank had been fitted, 1,620km/1,007 miles).

I-360, SM-2

Essentially, this was a parallel design to Aircraft M, but powered by a pair of slim Mikulin axial-flow engines of the type already flown in the SM-1, I-340. It led to the MiG-19, a brilliant pioneer supersonic fighter. Remarkably, this enjoyed only limited success in its own country. Its outstanding manoeuvrability was considered redundant in an age of missiles, and its guns an anachronism. A decade later it was a shock to Soviet leaders and the MiG OKB to discover its rebirth and global export success beyond the Great Wall of China.

On 30 July 1950, a month after the order to build the I-350, Mikoyan was summoned to the Kremlin. Stalin announced that twin axial engines were to be used in two new aircraft distinguished by their long range, of at least 2,000km (1,242 miles). One was to be a two-seat radar-equipped interceptor; this demand was met by the Yak-25. The other was to be a more agile single-seater, with a steep and rapid climb and the ability to cruise for long distances escorting bombers with one engine inoperative (an idea later shown to be impracticable). This was assigned to Mikoyan, the directive being dated 10 August 1951.

Designated I-360, and known in the OKB as the SM-2 (though apart from the engines it had little in common with the SM-1), the new twin-engined fighter was assigned to deputy chief constructor A G Brunov. Thanks to the SM-1 it was expected that the slim Mikulin AM-5A engines would give little trouble (unlike the TR-3A), and propulsion was assigned to Gleb Ye Lozino-Lozinskiy. Other section heads were A A Chumachenko (aerodynamics), V M Yezuitov (flight control), A V Minayev (systems), D N Kurguzov (stress analysis and drag) and N I Volkov (armament). The wing was to be based on the CAHI shape derived for Aircraft M, but with area



I-360/1, SM-2/1. (OKB)

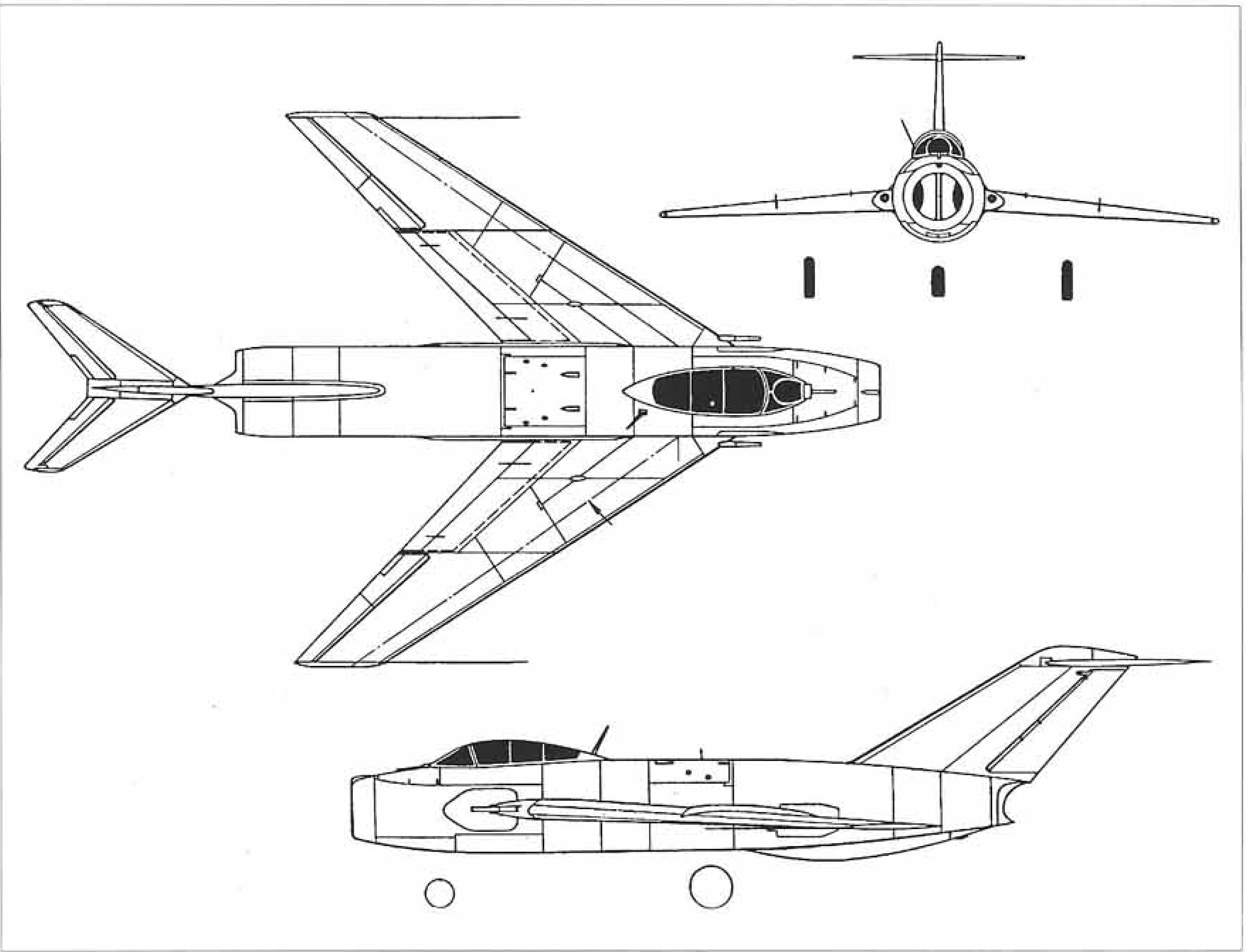
reduced from 36 sq m (387.5sq ft) to only 25sq m (269sq ft).

Thanks to the much smaller engines, the fuselage could be shorter than that of the M, the length from inlet to nozzles being 10.285m (33ft 9in) compared with 13.192m (43ft 3⅜in), but this was still considerably longer than the equivalent dimension for the SM-1 of 8.603m. Thus, it was clear that the new fighter would be larger than its predecessors, a major reason being the fuel capacity needed to meet the demand for long range. On the other hand, despite the much greater weight, wing area was little more than that of a MiG-17, and because of the greater sweepback the span was actually reduced. This posed a challenge to Rostislav A Belyakov, previously Volkov's assistant on armament, who was told to manage high-lift devices.

Aerodynamically the wing resembled a smaller version of that of the M, but with sweepback at the ¼-chord line reduced from 57° to 55°. As before, CAHI profiles SR-12s and SR-7s were used, average thickness/chord ratio being 8.24 per cent. Incidence was zero, and anhedral was increased to –4°30′. Aspect ratio was 3.26, and taper ratio 3.04. The leading edge was fixed, and in contrast to Aircraft M there was only a single fence above each wing, extending across the chord at the inboard end of the aileron. Each aileron was divided into two, the inner section having a tab, with internal aerodynamic balance and a total area aft of the hinge of 1.56sq m (16.8sq ft). As a result of CAHI model testing, interceptors – narrow-chord hinged flaps – were provided under the wing immediately ahead of each aileron, opened when the adjacent aileron was driven downwards. The Fowler flaps travelled out directly to the rear to 15° for takeoff and 25° for landing. Structurally, the wing had spars running straight from root to tip and ribs perpendicular to the leading edge. The flaps, unlike the ailerons, had ribs (twelve) parallel to the aircraft longitudinal axis.

Everything possible was done to reduce frontal area in order to achieve supersonic speeds. The fuselage diameter in fact was the same as that of previous MiG fighters, and like the I-340 the cross-section changed aft of the wing to a flat oval. At the trailing edge of the wing a double frame provided for the rear fuselage to be disconnected for access to the engines, the long jetpipes having to be removed as well. No details are known of the fuel system.

The tail was derived from what had gone before, with the single innovation of placing the horizontal surface at the very top of the fin. The latter had S-11 profile with a straight leading edge swept at 57°30′ with no dorsal fin or spine along the fuselage. Control rods ran inside the fuselage, and a major reason for the high tailplane was that it enabled the rudder to be a single surface. Like the wings, the tailplane was much smaller than that of the M, span being 2.78m (9ft 1½in) and area 3.47sq m (37.35sq ft), the leading-edge sweep being 55°. For the first time it was a primary control surface, the tabbed elevators being geared to increase camber.



I-360.

All flight-control surfaces were boosted by duplicated tandem hydraulic actuators, with feedback giving artificial feel. Each engine drove a pump to serve duplex systems each with a cutout pressure of 207MPa (3,000lb/sq in), with certain services provided with standby power from pneumatic storage bottles. The left-engine pump served the Booster (flight control) system and the right-engine pump served the Utility system which operated the flaps, landing gear, underwing interceptors and airbrakes.

Whereas OKB drawings of the SM-2 show rectangular airbrakes immediately behind the wings, they were actually again positioned on each side at the extreme tail end of the fuselage. Each was very long but narrow and tapering, and incorporated a large blister down the centre to accommodate the actuating ram underneath. They opened to 65°. The landing gear again followed established principles, but the main units had a door arrangement similar to that of the MiG-17, with separate leg and wheel doors both linked to the leg, unlike Aircraft M. Each main wheel had a 660 × 200mm tyre (actual width 180mm) and the forwards-retracting castoring nose unit had a tyre designated 500 × 180mm (actual width 160mm).

Volkov devised a totally new armament installation. The chosen armament was two N-37D cannon, installed in the roots of the wings. Among the advantages of this arrangement were that the guns and their 100-round magazines occupied spaces inside the wing which were otherwise unused, and in most flight conditions none of the blast and gun gas could interfere with airflow into the engines. One of the few drawbacks was that it involved cutting a large hole in the most highly stressed part of the main spar. The fuselage skin near each muzzle was reinforced by a panel of heat-resistant steel.

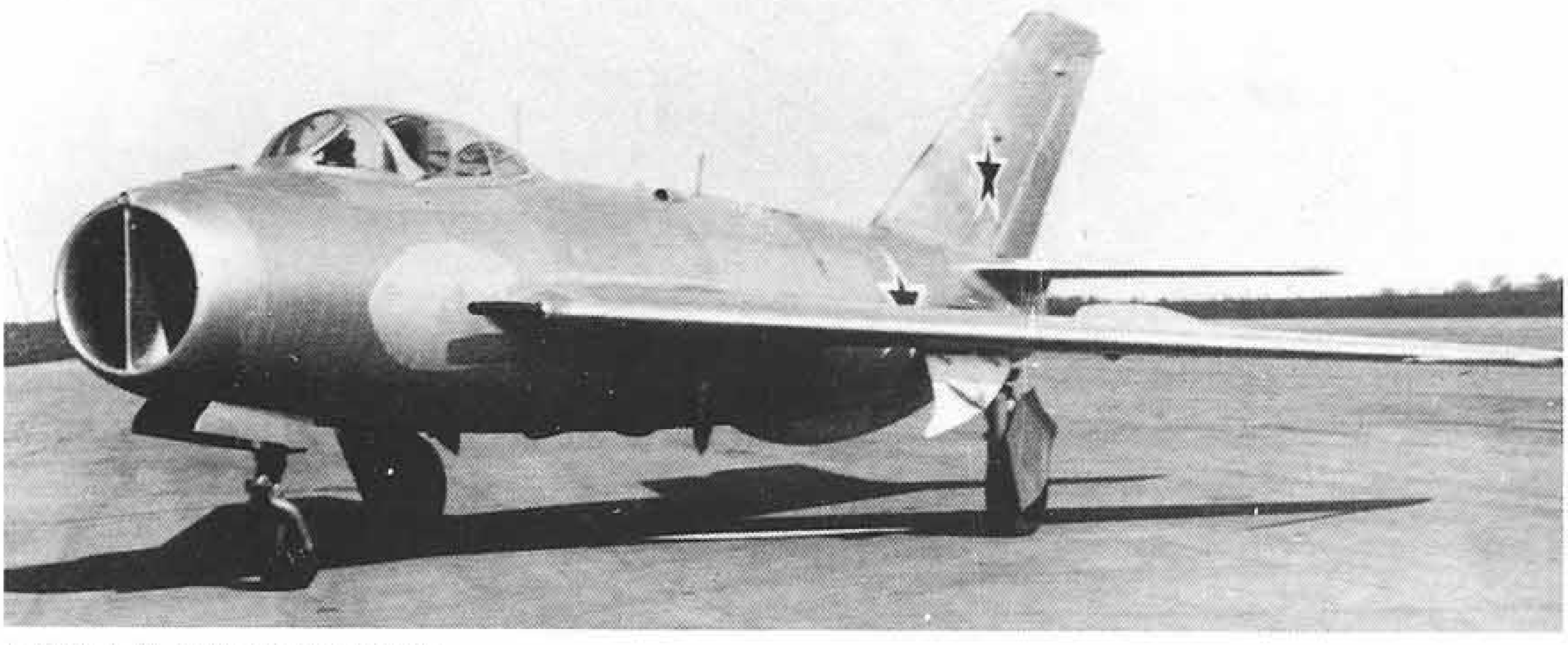
The nonafterburning AM-5A engines were virtually identical with those fitted to the I-340. Each was rated at 2,000kg (4,409lb), and they were installed as close together as possible though with a thin steel firewall between them. The fixed-area nozzles were surrounded by a rear fuselage similar in shape to the I-340 or even the MiG-17 (though the OKB three-view of the original SM-2 project shows a 'pen nib' fairing, which was not introduced until the SM-9/1). Each engine bay was cooled by air rammed in at two protruding inlets on top of the fuselage ahead of the break point.

The pressurized, heated and cooled cockpit had a flat bulletproof windscreen with alcohol de-icing, and a rearwards-sliding canopy incorporating two intermediate transverse frames. The seat was of the same OKB-developed face-shroud pattern as used on all the MiG fighters of 1952 vintage, adjustable to three positions over a vertical range of 120mm (4.7in). Above the fuselage were blade antennas for an RSIU-3 vhf radio and an ARK-5 radio compass, the latter sharing a display with the DGMK-5 gyrocompass. An S-13 camera was mounted at the top of the nose. A long pitot tube projected ahead from each wingtip, that on the starboard wing serving navigation instruments and the port probe the remainder. The dipole antenna of the RV-2 radar altimeter projected diagonally from under the rear fuselage on the left side ahead of the ventral strake.

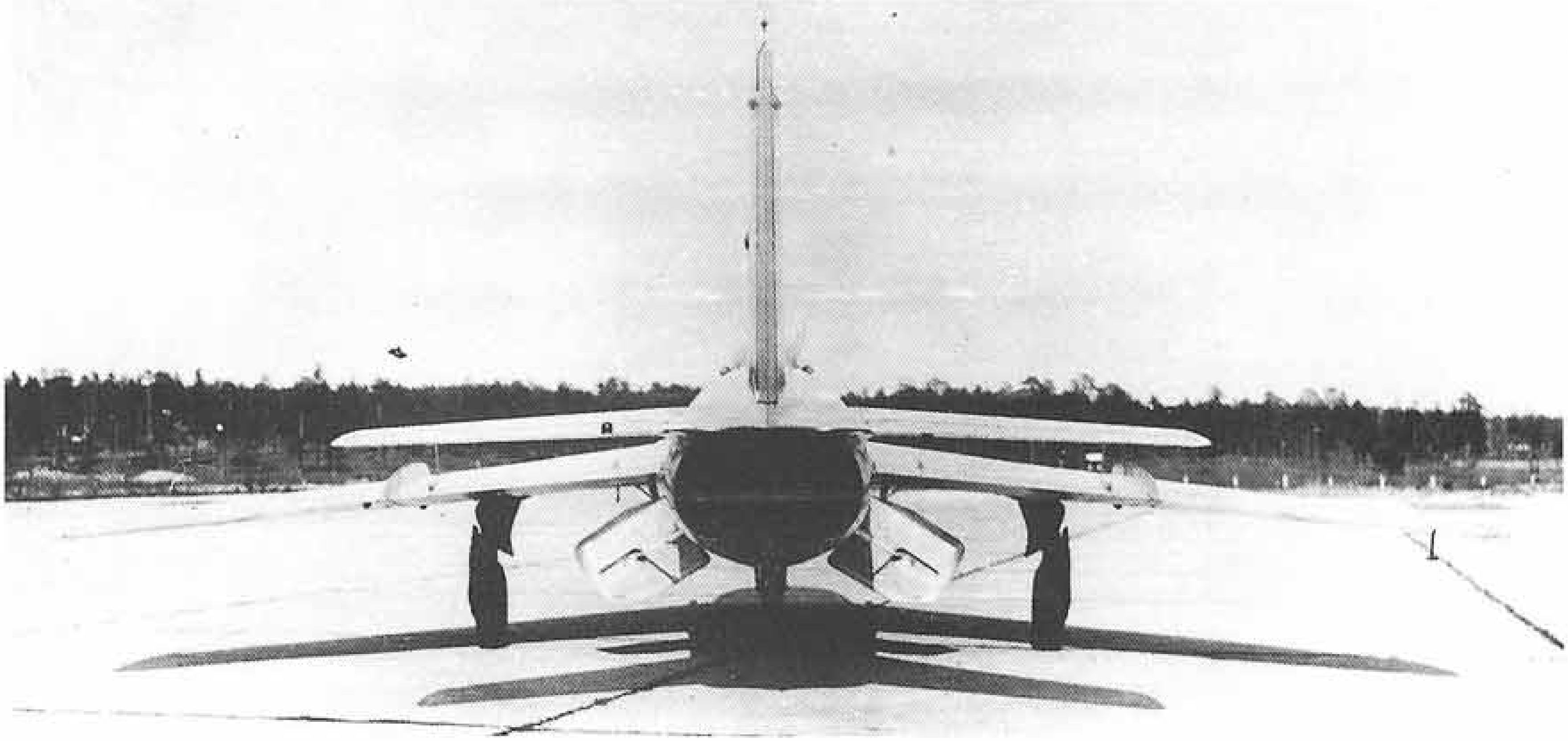
The OKB received an order for two I-360 prototypes. The first, called SM-2/1 or SM-2 No. 1, was completed in April 1952, taken to the LII-MAP test airfield at Zhukovskiy and flown there on 24 May 1952 by the assigned OKB pilot, G A Sedov. Though performance and handling were generally good, it was soon evident that with AM-5A engines the maximum speed was still marginally subsonic. The highest speed reached with an SM-2 in a shallow dive was Mach 1.19, equivalent to about 1,283km/h (797mph).

OKB records are sparse. At some point the AM-5A engines were replaced by AM-5F engines with long afterburners fitted with two-position variable nozzles. Two additional ram inlets were provided to cool the structure around the afterburners. These engines increased maximum thrust at sea level to 2,700kg (5,952lb), yet there is no record of this making either SM-2 supersonic in level flight, and it may be that sustained afterburning thrust was never achieved.

The horizontal tail was lowered for two entirely different reasons: at transonic Mach numbers it became increasingly ineffective, and buffeting was encountered at high angles of attack, when the wing wake not only approached the horizontal tail but also became more turbulent. Thus, it was



I-360, SM-2/1, with low tailplane. (OKB)



I-360, SM-2/1, with low tailplane; airbrakes open. (OKB)

encountered at low speeds, and at higher speeds it was manifest in hard turns and dive pull-outs.

The answer was to relocate the horizontal tail at the top of the rear fuselage, and this appears to have been done in autumn 1952, though records are lacking. The OKB was reluctant to do this redesign, because the sense of urgency at the height of the Korean and Cold wars was pressing, and there was no time to do detailed tunnel testing. Moreover, because of the reduced moment arm, the new tail had to be much larger and so had higher drag. In the subsequent forty-five years the OKB has never again designed a high T-type tail, except for the MiG-AT, where such a tail was abandoned.

A completely new horizontal tail was designed, with much greater chord, with span increased from 2.78 to 4.59m (15ft 0¾in) and area increased from 3.47 to 5.50sq m (59.2sq ft). The new horizontal tail had the tailplane fixed rigidly to the fuselage, with boosted tabbed elevators. The low tailplane in turn demanded a redesign of the airbrakes. The new panels were almost rectangular, shorter but deeper than before, and moved further forwards so that the trailing edge of the brake was below the leading-edge root of the tailplane. Their area was increased to 1.07sq m (11.5sq ft) each.

There is no evidence that the location of the wing fences was altered. Modifications that were effected included adding muzzle brakes to the guns, installing collector boxes for the spent 37mm cases to avoid tail damage, adding a *Radal*-M radar ranger to the ASP-4N gunsight, fitting an SRZO *Uzel* IFF and relocating the RV-2 antenna under the starboard wingtip. The modification programme was supervised by V V Mel'nikov, chief engineer of SM-2/2.

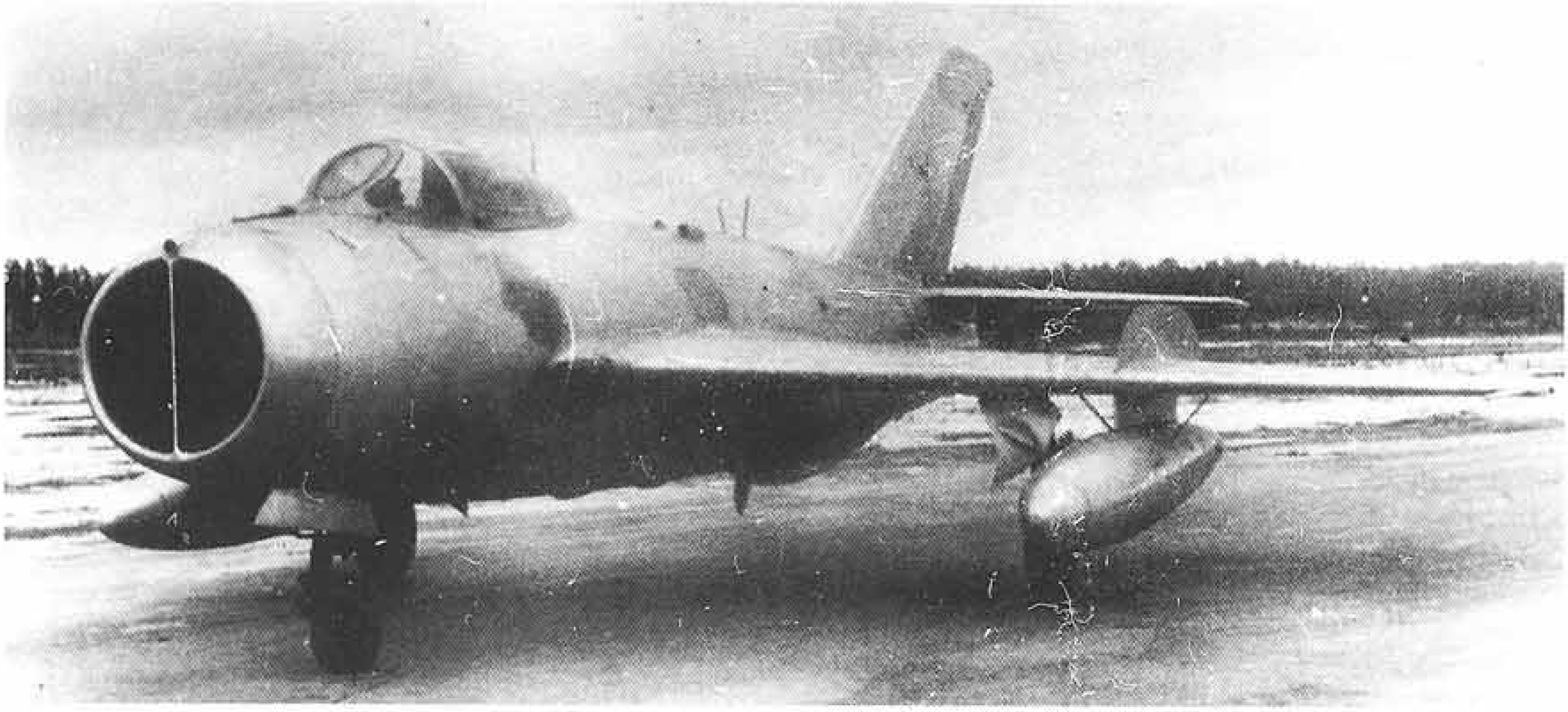
The SM-2/2, the second prototype, was completed with the original high tail, but with a different flight-control system. The ailerons and elevators were driven by irreversible tandem hydraulic power units which were each unidirectional in their operation. To initiate feel, a special spring unit was incorporated in the drive from the stick. With landing gear retracted, a second spring unit was brought into play to prevent overcontrol. At speeds over 700km/h (435mph) control would otherwise have been oversensitive.

In addition to Sedov the SM-2 test pilots included V G Ivanov for the OKB, and V S Kotlov, A Rogatnyev and A P Suprun for the NII-VVS. On several occasions control was lost. On one, Rogatnyev opened the airbrakes at high indicated airspeed and thereafter suffered violent overcontrol in pitch. After severe positive and negative g, he was able to grip the sides of the cockpit, letting go of the stick, whereupon the rollercoaster ride ceased; he closed the throttle and resumed normal control. During NII-VVS testing Ivanov found a steep turn changed into an uncontrolled nose-up pitch which resulted in a stall/flick/spin. Control was regained after a loss of height of 8,000m (26,250ft).

To cure these problems the sensitivity of the elevators was reduced, the horizontal tail was brought down slightly lower on the fuselage (moving it completely clear of the fin) and the wing fences were made three times as large by increasing their height to one eighth of the wing chord. The new tail design was assisted by testing the SYe (MiG-15LL).

In late 1953 Sedov was near the airfield at 500m (1,640ft) when both engines lost power (apparently they flamed-out). The aircraft had almost a full fuel load, and though he recovered to the airfield with landing gear extended the aircraft hit the ground short of the runway and was damaged. It was then set aside for further modifications as the SM-9/1. The SM-9 front-line fighter was one of three new MiG prototypes ordered in a single Kremlin directive dated 15 August 1953, the others being the SM-7 all-weather interceptor and the I-370 (I-1) powered by a single VK-7 engine.

In 1953 the production Factory No. 21 at Gor'kiy began to tool up to make what was expected to be designated the MiG-19. There is evidence to indicate that the factory actually manufactured a small batch of SM-2B aircraft in production tooling. Powered by the AM-5F engine, these were apparently operated by a VVS unit which was



I-360, SM-2/2. (Yefim Gordon archive)

issued with a document entitled 'GK-151', giving instructions to pilots on how to fly the SM-2. In fact the series aircraft, the MiG-19, was to be based on the re-engined SM-9.

Span 9.04m (29ft 7⅞in); length 13.9m (45ft 7¼in); fuselage length 10.285m (33ft 9in): wing area (OKB approximation) 25sq m (269sq ft).

Weight empty 4,929kg (10,866lb); weight loaded 6,820kg (15,035lb).

Maximum speed, not stated but about Mach 1 at high altitude. No other data recorded.

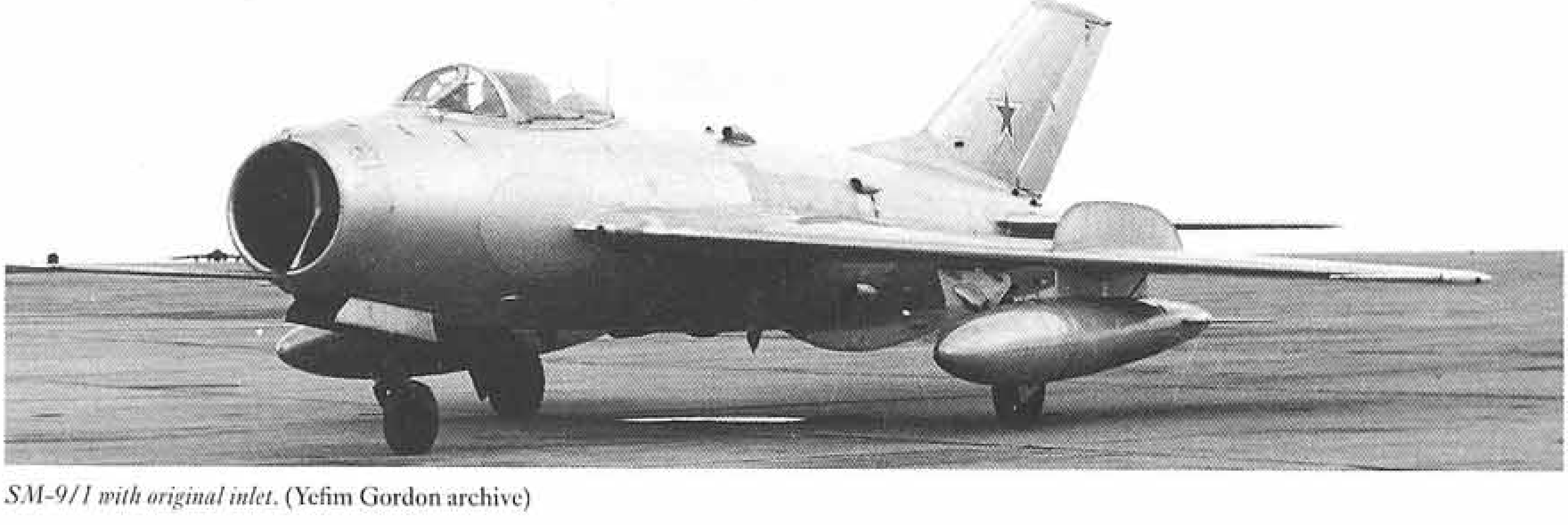
MiG-19, SM-9

The SM-9 was one of three new MiG aircraft ordered in a single directive (No. 2181-887) of 15 August 1953. Essentially it was a day frontal fighter similar to the latest standard of SM-2, but with improved engines. These were designated AM-9, but after Mikulin's fall from favour in 1956 they were redesignated RD-9. The design team was actually led by S K Tumanskiy, who took pains to make the improved engine a bolt-on replacement for the AM-5, minimizing the need for aircraft modification.

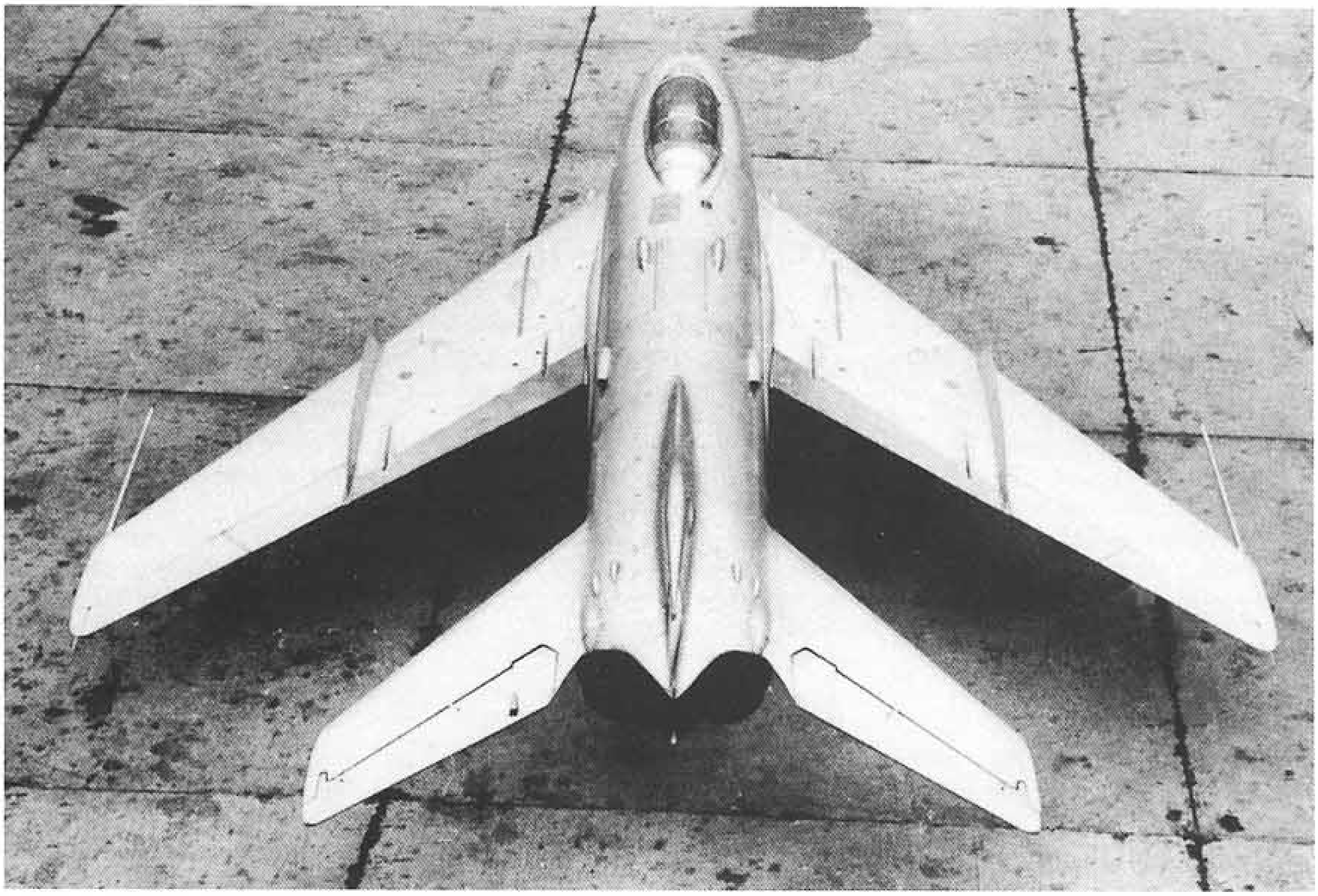
Compared with the AM-5 the AM-9 had an improved nine-stage compressor which increased pressure ratio from 5.8 to 7.5, and increased mass flow from 37.5 to 43.3kg/s (95.5lb/s). Turbine entry temperature was increased from 1,130 to 1,150 °K (877 °C, 1,611 °F), at which level maximum thrust was 2,600kg (5,732lb) dry and 3,250kg (7,165lb) with afterburner. All these values are for maximum power at sea level. The prototype engines were accompanied to the Mikoyan bureau by two Mikulin engineers, I I Gneushev and V P Shavrikov.

OKB engineers calculated that with this engine the SM-9 would at last be a true supersonic fighter. The only modifications needed by the more powerful engine were minor heat shields and two additional cooling intakes to keep down structural temperatures around the afterburners. To prevent compressor stalls, the throttle linkage of the starboard engine was fitted with a limiter unit. The inlet ducts were unchanged, but the splitter in the inlet was cut back in an inward-facing V-shape. A total of 2,170 litres (477gal) of fuel was housed in two large rubberized-fabric cells behind the rear pressure bulkhead and two shallow tanks under the jetpipes.

There were, however, other changes. The most important was that armament was changed to three NR-23 guns, one in each wing root and the third low down on the right side of the forward fuselage. Each had



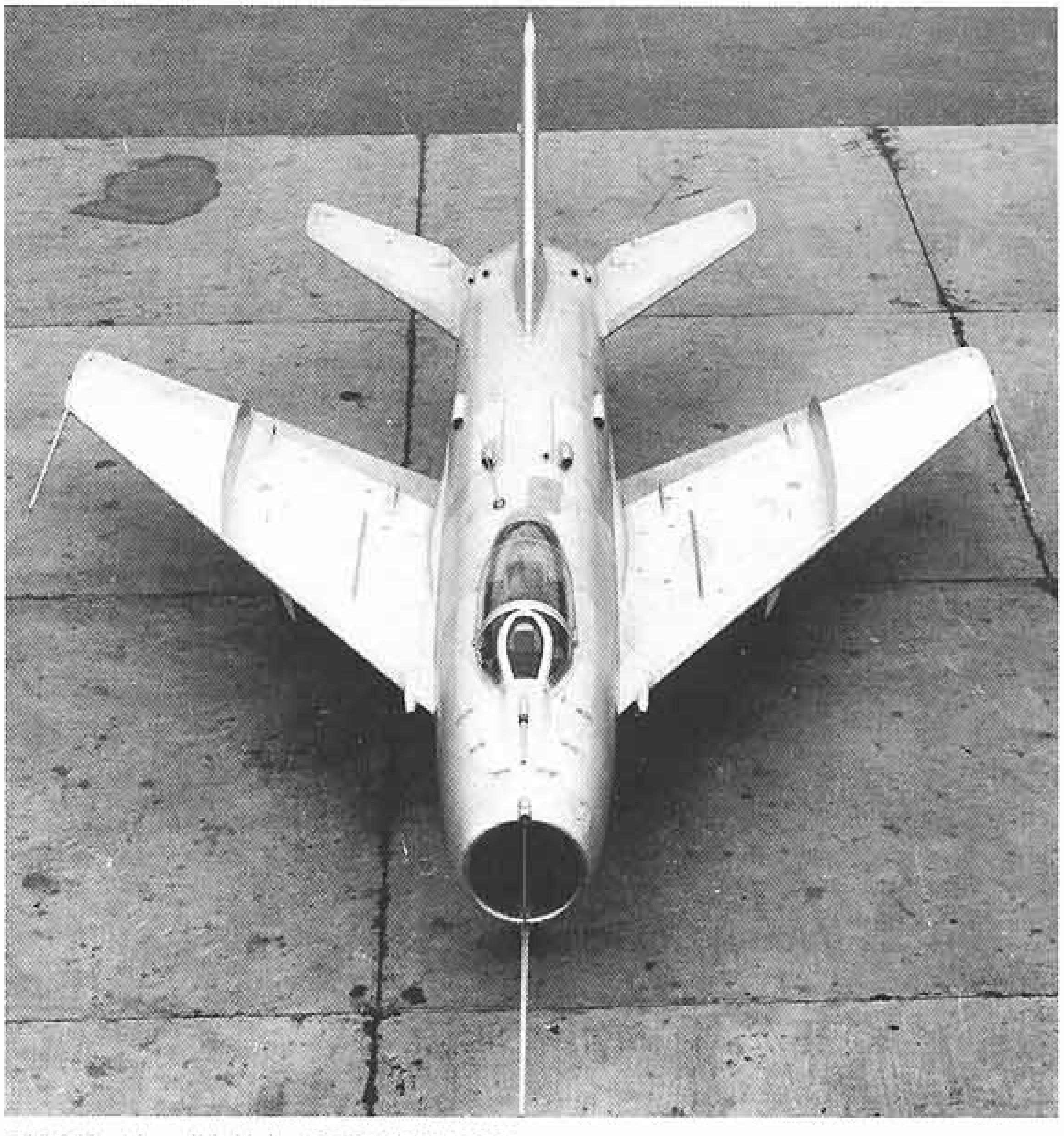
SM-9/1 with original inlet. (Yefim Gordon archive)



SM-9/1. (Yefim Gordon archive)

a magazine with 110–120 rounds, the cases and links being collected. The wings were designed for a total of four pylons, the outers being plumbed for 760lit (167gal) drop tanks as an alternative to an ARS-57 rocket launcher and the inner pylons behind the main landing gear taking interfaces for an ARS-57 or BD-3-56 racks for bombs up to 250kg. Shallow chordwise stiffeners were added across the top of the inner wing above the landing-gear well. The vertical tail was restressed, and fitted with a dorsal fin. A braking parachute was housed in a box under the rear fuselage. An additional long air-data boom was fitted at the bottom of the nose, arranged to pivot up to avoid damage when the aircraft was parked.

The airbrakes were slightly modified and their angle reduced to 50°. The Utility hydraulic system was extended to actuate the engine nozzles, linked to afterburner fuel flow. The flight-control hydraulics were refined, and the elevator fitted with an artificial-feel unit linked to the UT-6D trimmer servomotor. The canopy was fitted with electrothermal demisting, and new avionics included the



SM-9/1 with modified inlet. (OKB, RART/GP)

RSIU-3M *Klyon* (maple) vhf with a range at high altitude of 350km (217 miles), sharing its antenna with the ARK-5 whose antenna was omitted, an SRD-1M *Konus* (cone) radar ranger with limits of target range from 300m to 2km, and the *Uzel*-1 (later renamed *Khrom*, chrome) IFF set.

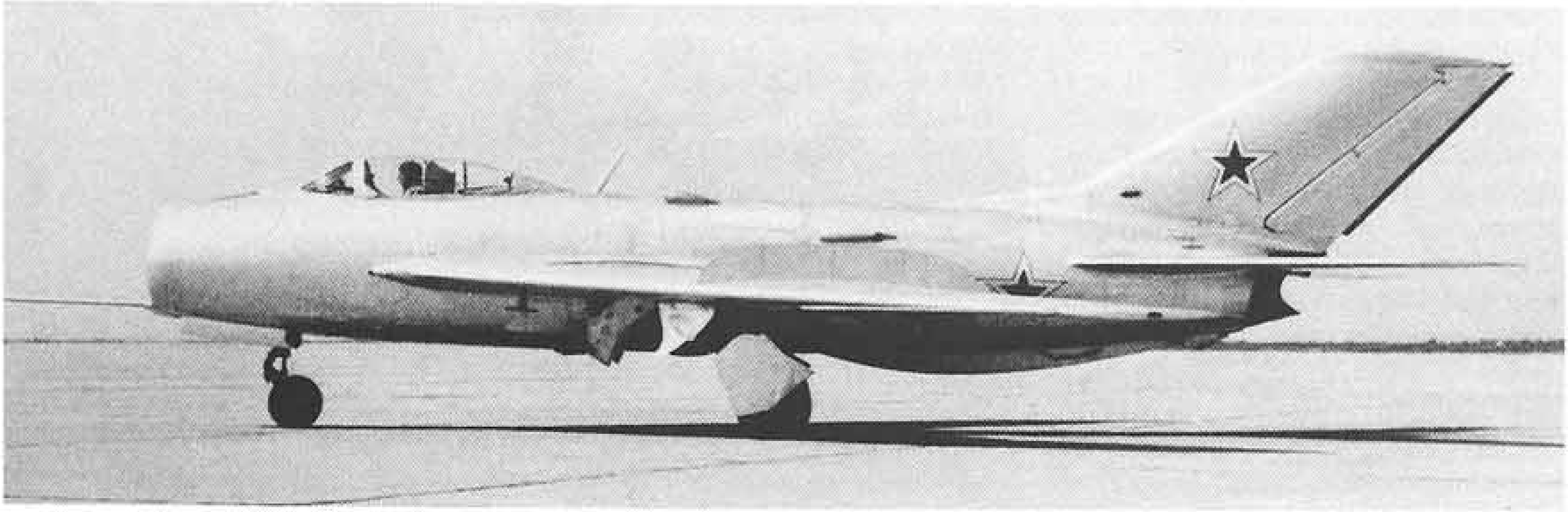
The SM-9/1 was the SM-2/2 repaired and modified. Chief engineer was V A Arkhipov, assisted by V A Mikoyan (second son of brother Anastas). The task was considerable, and Sedov was not able to begin the factory flight-test programme until 5 January 1954. On the second flight Sedov climbed to altitude and selected afterburner, noting rapid acceleration to well beyond Mach 1. The inlet splitter was soon modified to be vertical, like other MiG aircraft. The tail end of the fuselage was modified in a V-shape seen from above, giving the so-called 'pen-nib' shape between the nozzles.

Though still imperfect, this aircraft was clearly a world-beater, with supersonic speed on the level, excellent manoeuvrability and a sustained rate of climb of 180m/s (35,430ft/min). According to pilot-engineer A Solodovnikov 'At 700km/h ram effect increased total thrust by 1,000kg, and at 1,400km/h the increase was 1,870kg. Thus, total thrust was equal to the weight of the aircraft'. This was theoretical, because such thrusts were possible only at low altitude, where supersonic speeds were not possible.

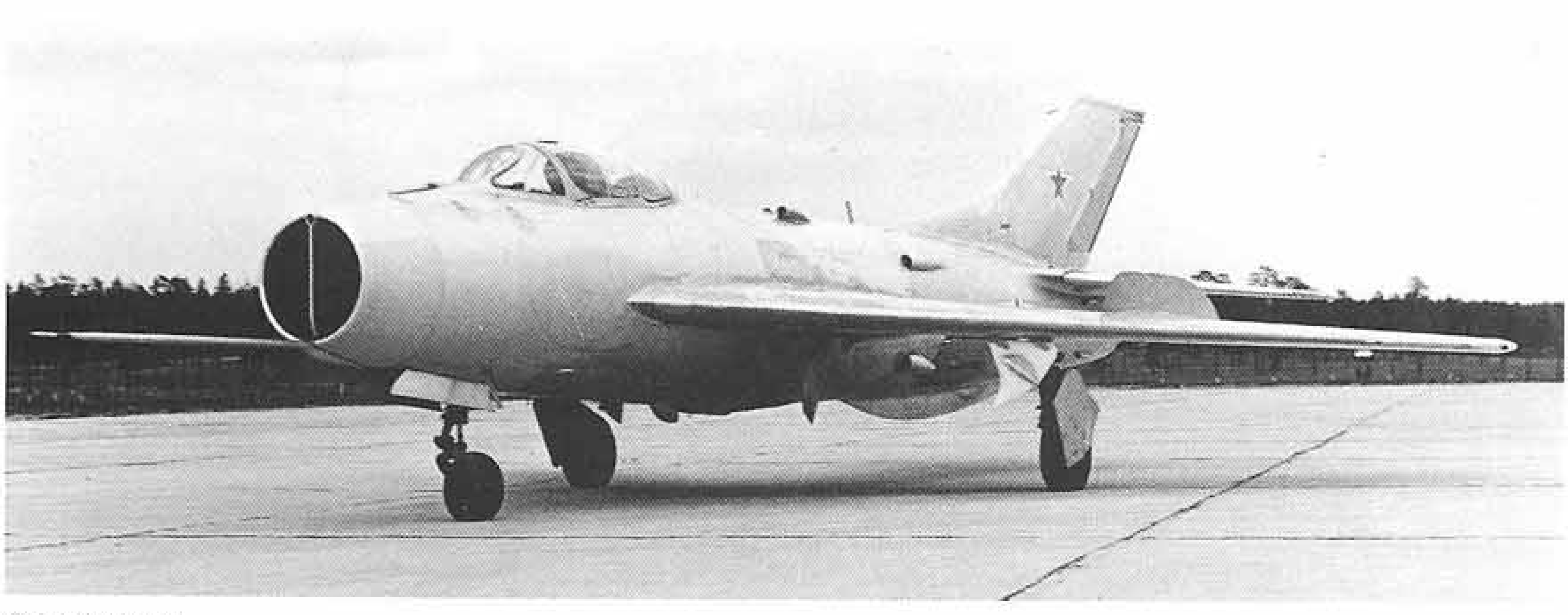
Ministerial decree 286-133 took the unusual step of ordering the start of production on 15 February 1954, with the Service designation MiG-19. The factories at Gor'kiy (No. 21) and Novosibirsk (No. 153) were told to begin production in advance of State testing, using copies of OKB drawings, production drawings not yet being ready. The initial order was for one hundred aircraft, split fifty-fifty. Many of these aircraft were used in special test programmes.

Though other factory pilots flew the SM-9/1 Sedov did the bulk of the testing, in 132 flights. Factory testing was completed on 12 September 1954, and on 30 September, with series aircraft starting to appear, NII-VVS testing began. NII pilots were V G Ivanov, Yu A Antipov and N A Korovin, supported by test engineer Yu Kalachev. Together with factory pilots they courageously explored handling to the limits, finding unacceptable characteristics. These included a progressive reduction in pitch control effectiveness at supersonic speeds; occasional dangerous phugoids (rollercoaster) control loss in the vertical plane; and sudden severe increase in stick forces following deceleration from supersonic speed.

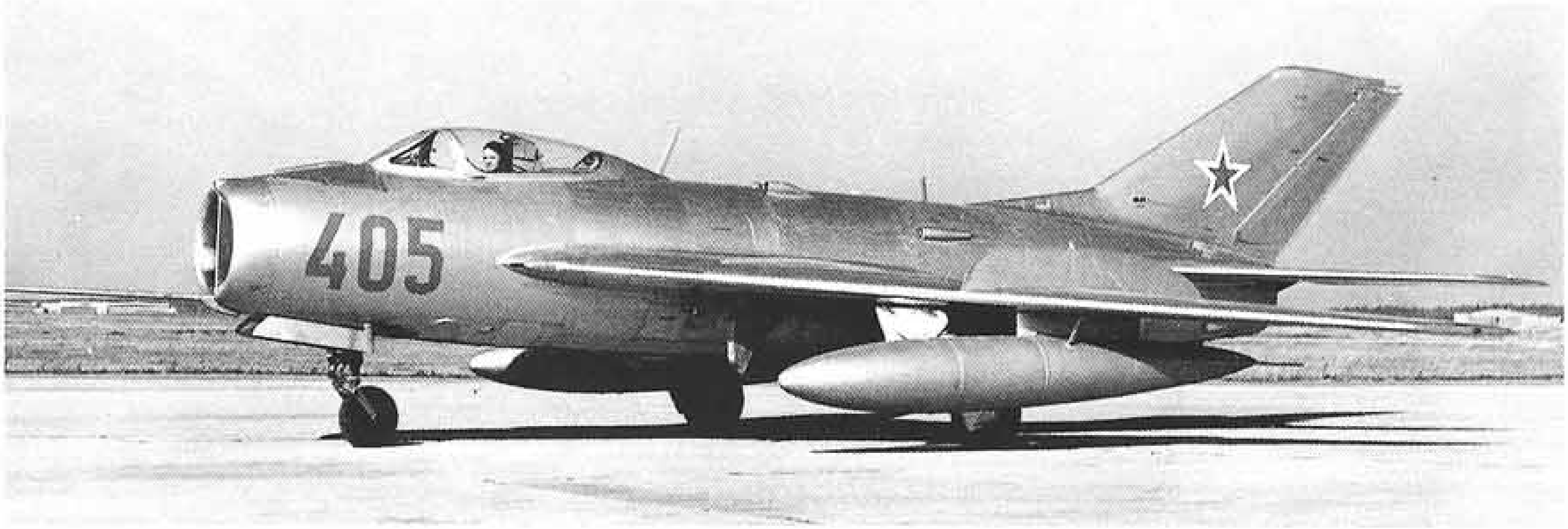
These problems were to be explored by two additional prototypes SM-9/2 and -9/3, ordered in January 1954. Meanwhile, the MiG-19 entered service from March 1955. The new fighter became known in the West when forty-eight flew in the Tushino parade on 3 July 1955. Four aircraft painted red and white formed an aerobatic team, led by Gen-Col Yevgeniy



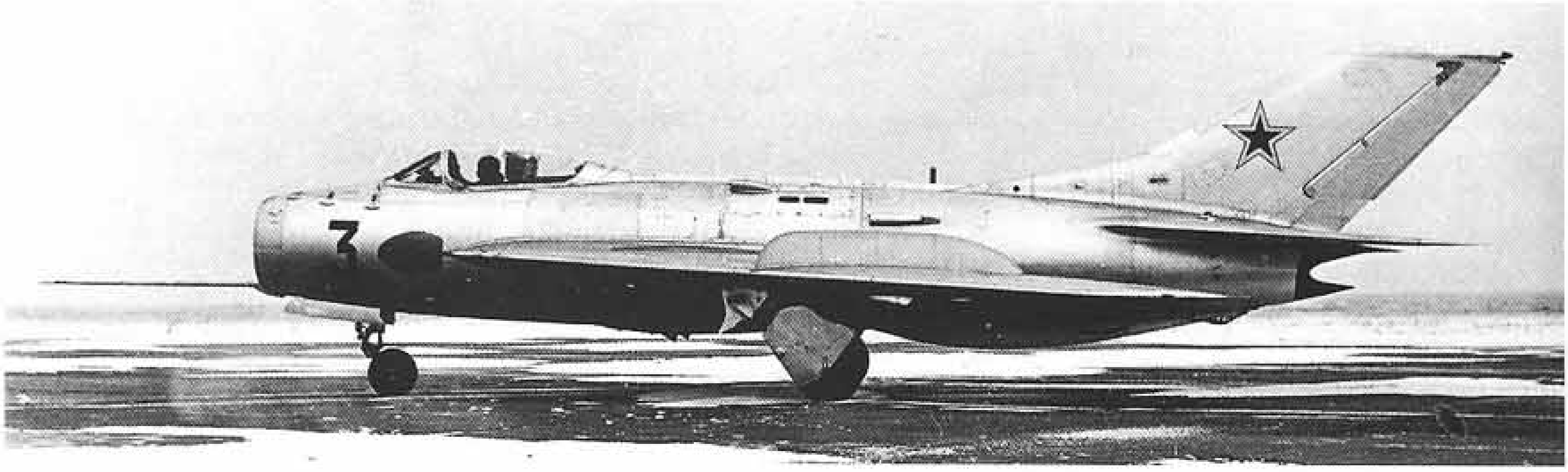
SM-9/1. (OKB, RART/GP)



SM-9/2. (OKB)



One of the first production MiG-19s. (RART/GP)



SM-9/3. (OKB)

Savitskiy, Commander of the IA-PVO. The ASCC allotted the name 'Farmer'.

Span 9m (29ft 6⅜in); length 14.8m (48ft 6⅝in), (excluding air-data boom) 12.54m (41ft 1¾in); wing area 25.16sq m (271sq ft).

Weight empty 5,095kg (11,232lb); internal fuel 1,800kg (3,968lb); weight loaded (clean) 7,470kg (16,468lb), (maximum) 8,500kg (18,739lb).

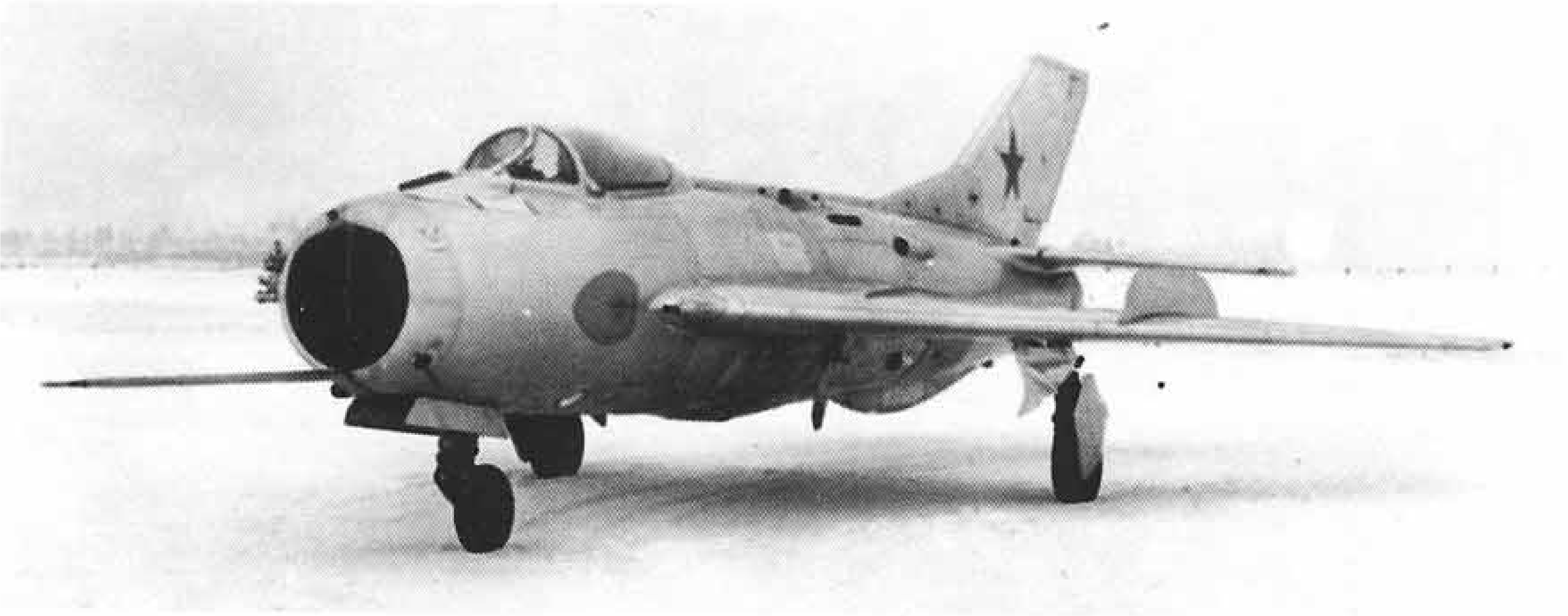
Maximum speed 1,150km/h (715mph) at sea level, 1,452km/h (902mph, Mach 1.367) at 10,000m (32.808ft); climb to 10,000m (32,800ft) 1.1min, to 15,000m (49,215ft) 3.7min; service ceiling 17,500m (57,415ft); range 2,200km (1,367 miles).

MiG-19S, SM-9/3

The OKB had for several years considered the concept of the 'slab' horizontal tail, in which each tailplane is itself pivoted and used as the primary control surface in pitch, without the need for separate hinged elevators. Technical difficulties, both structural and concerning the drive mechanism, had prevented its realization until the MiG-19 problems demanded a further look at the possibilities.

Accordingly, SM-9/2 was boldly fitted with one-piece left and right 'slab' tailplanes, or 'stabilators', with no elevators, total area being 7.87sq m (84.7sq ft). On one occasion Ivanov had found loss of elevator effectiveness on SM-9/1 caused by a turbulent wing wake, so on SM-9/2 the tailplanes were mounted slightly higher than in SM-9/1, almost back in the SM-2 location. Each tailplane was mounted on a pivot at 90° to the longitudinal axis outboard of a broad fixed root. The tailplanes were driven over the range +11.5°/–26.5° by the specially developed BU-14MS irreversible power unit, served by the Booster (flight-control) hydraulic system, with a pump on the port engine. Pressure could be transferred from the Main (Utility) system, with the pump on the starboard engine, should pressure in the Booster system fall below 65kg/sq cm (924.5lb/sq in). With pressure below 50kg/sq cm (711lb/sq in) a third fallback, with reduced authority, was available in an APS-4 irreversible electric screwjack, which could also be switched on by a button on the stick. A rocking switch on the stick controlled the MP-100M trimmer motor.

The dorsal fin was enlarged, giving total fin area of 4.17sq m (44.9sq ft), though total vertical tail area was reduced from 5.5 to 5sq m (53.8sq ft). The rudder was reduced in height by raising its bottom edge, and fitted with a sharp strip along the trailing edge. The ailerons were also modified and driven over the limits ±20° by BU-13M irreversible power units, the underwing aileron interceptors being retained. The airbrakes were slightly modified, and limited to an angle of 25°, and a third airbrake was added in a new bulge under the centre fuselage. This brake was again hinged at the front, but it was short and broad and had six large perforations. It opened to 45°. The wingtip pitot booms were omitted.



MiG-19S. (OKB)

Following instances when VVS pilots found difficulty in jettisoning MiG-19 canopies, the canopy of the improved aircraft was for the first time fitted with a positive jettison system energized by twin air bottles. New equipment included RSIU-4 *Doob* (oak) vhf radio, an ASP-5M gunsight (with SRD-1M radar ranging as before) and the OSP-48 ILS.

A unique feature of SM-9/2 was that the nose was lengthened, though this was found to be unnecessary. According to one document this aircraft was rolled out as early as January 1954. Whether or not this is so, it was first flown by Sedov on 16 September 1954. Later it was flown by K K Kokkinaki, V A Nefyodov and G K Mosolov. NII-VVS testing was handled by A S Blagoveshchenskiy, V G Ivanov, Yu A Antipov, G T Beregovoy (a future cosmonaut) and N A Korovin, who all wrote highly positive reports. By 4 May 1955, after fifty-eight flights, the flight-control system had been refined under Minayev to incorporate the ARU-2A artificial-feel system, which automatically varied the gearing between the stick and control surfaces according to Mach number. It incorporated a q-feel input to make stick force proportional to dynamic pressure.

The third prototype, SM-9/3, reverted to the short nose. It had slightly modified flight controls, and the tail control rods were mounted above the fuselage inside a spine. The armament was doubled in power (projectile weight per second rising from 9kg to 18kg, 40lb) by replacing the 23mm guns by the newly developed NR-30. Designed like the NR-23 by A E Nudel'man and A A Rikhter, these guns were of a calibre new to the USSR, and they were far more devastating than the British Aden and French DEFA of the same calibre, with much greater projectile weight and higher muzzle velocity. The fuselage gun had 55 rounds, and each wing gun 75. Cases were expelled overboard, but links were collected. All guns had prominent muzzle brakes, and in fact the steel fuselage panels adjacent to the wing-gun muzzles were reduced in size.

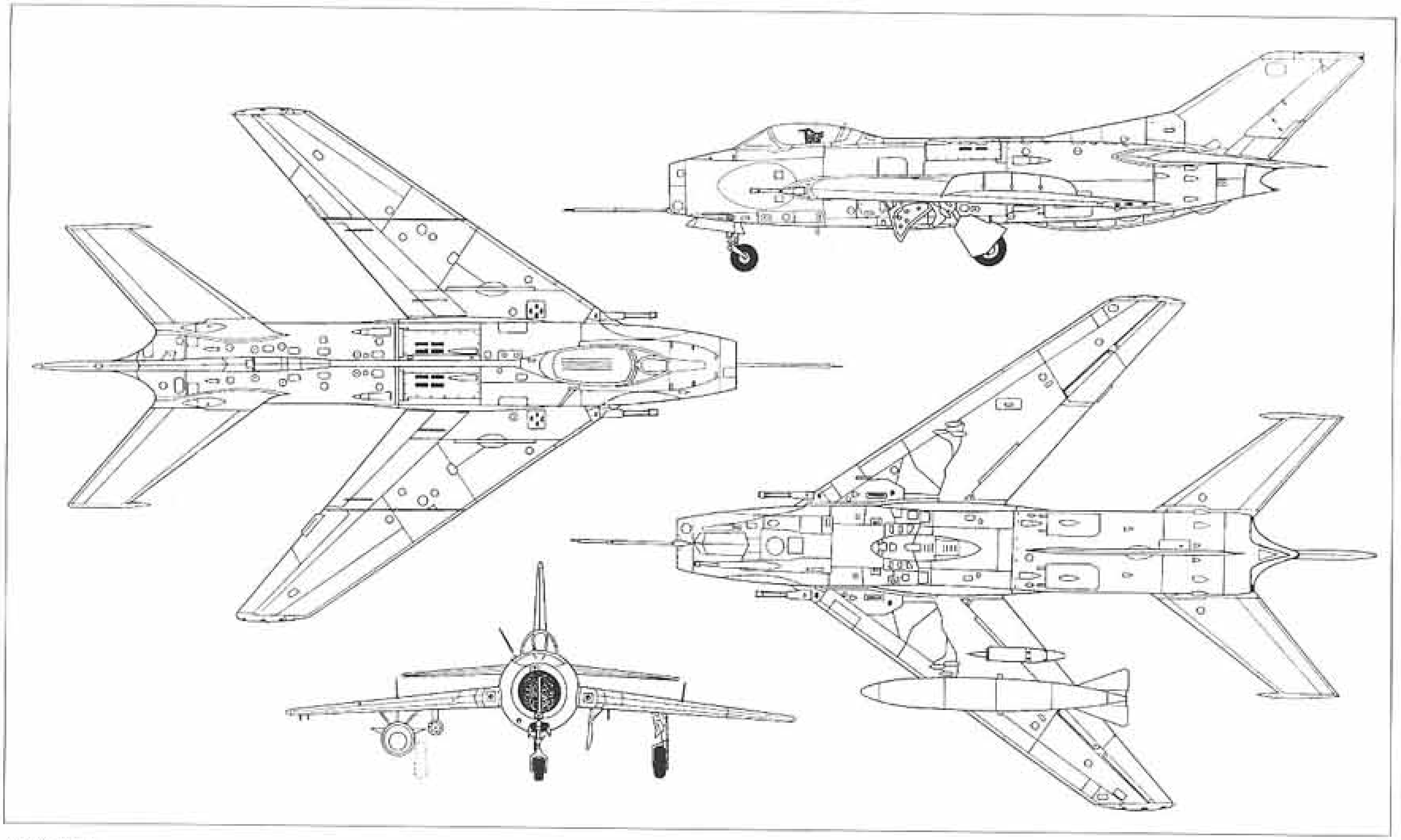
Bearing in mind the fact that SM-9/2 and SM-9/3 were ordered together, and were built in immediate succession in the OKB factory, it is remarkable that SM-9/3 was not rolled out and photographed until 26 August 1955. By this time the flight-control system was being modified and it was not flown until 27 November 1955, the pilot being Kokkinaki. On his third flight, at high speed, he encountered severe tailplane flutter, causing violent undulations which tested the wings to their limits. The stick was wrenched from Kokkinaki's hands, and he was injured by the flailing stick and by hitting parts of the cockpit, the landing being made with difficulty.

Mosolov took over SM-9/3, and he encountered the same problem, overstressing the airframe. The flutter was cured by adding heavy pointed rods ahead of the tip of each tailplane, and also by further modification of the flight-control system with different gearing and variation of stick limits. Other modifications included replacing the SRD-1M ranger by the new SRD-3 *Grad* (hail), installed just to the left of the camera at the top of the nose, and fitting a frameless canopy. Both prototypes were repeatedly spun by Sedov and Antipov, dived to Mach 1.46 and tested for fuel consumption and range. During NII-VVS testing A A Shcherbakov started a spin at over 18,000m, while Sergo Mikoyan (first son of brother Anastas) tested the ARU-2A artificial feel. Other NII-VVS testing was done by N P Zakharov and A F Nikolayev.

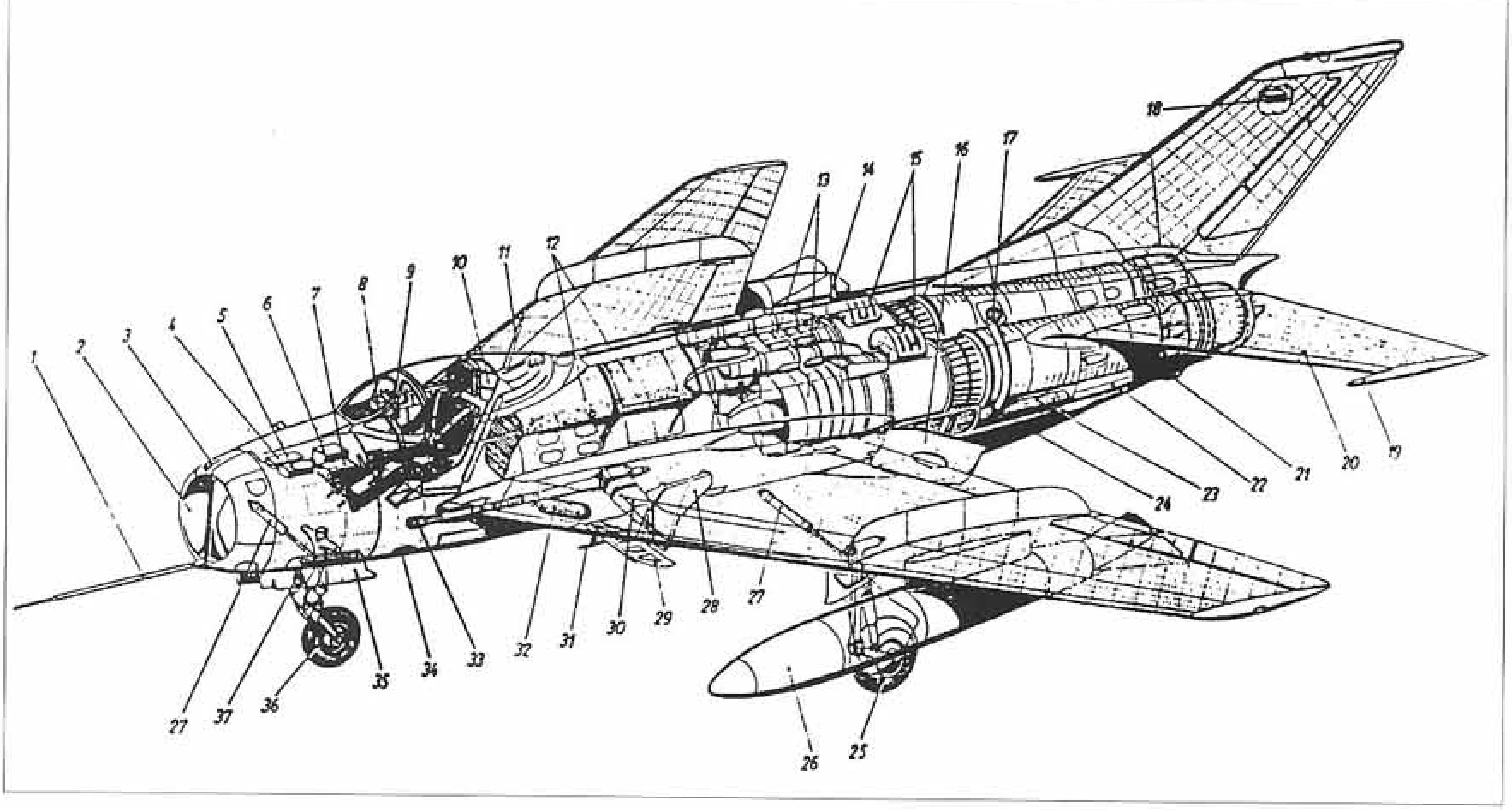
The resulting series aircraft was designated MiG-19S, S for *stabilizator* (the horizontal tail). In fact, like the Yak-25, it was never officially accepted for VVS service, one shortcoming being a failure to meet the requirement for range. Between them Gor'kiy and Novosibirsk delivered about 1,250, a trivial total by Soviet standards, from June 1956.

It is appropriate here to add descriptive notes of the MiG-19S, which in many details differed from the MiG-19. The airframe was almost entirely D-16 duralumin, with 30KhGSA and other high-strength steels used for spar booms and several joints. Each wing had 28 ribs, and large skin panels which between the spars were 4.8mm thick, more than double the maximum on the MiG-17.

The main fuselage, ending at Frame 20, incorporated the nosewheel bay (Frames 1–4), the cockpit (4–9), protected Tank 1 of 1,485 litres (327gal), protected Tank 2 of 330 litres (72.6gal), the wing attachments (9 and



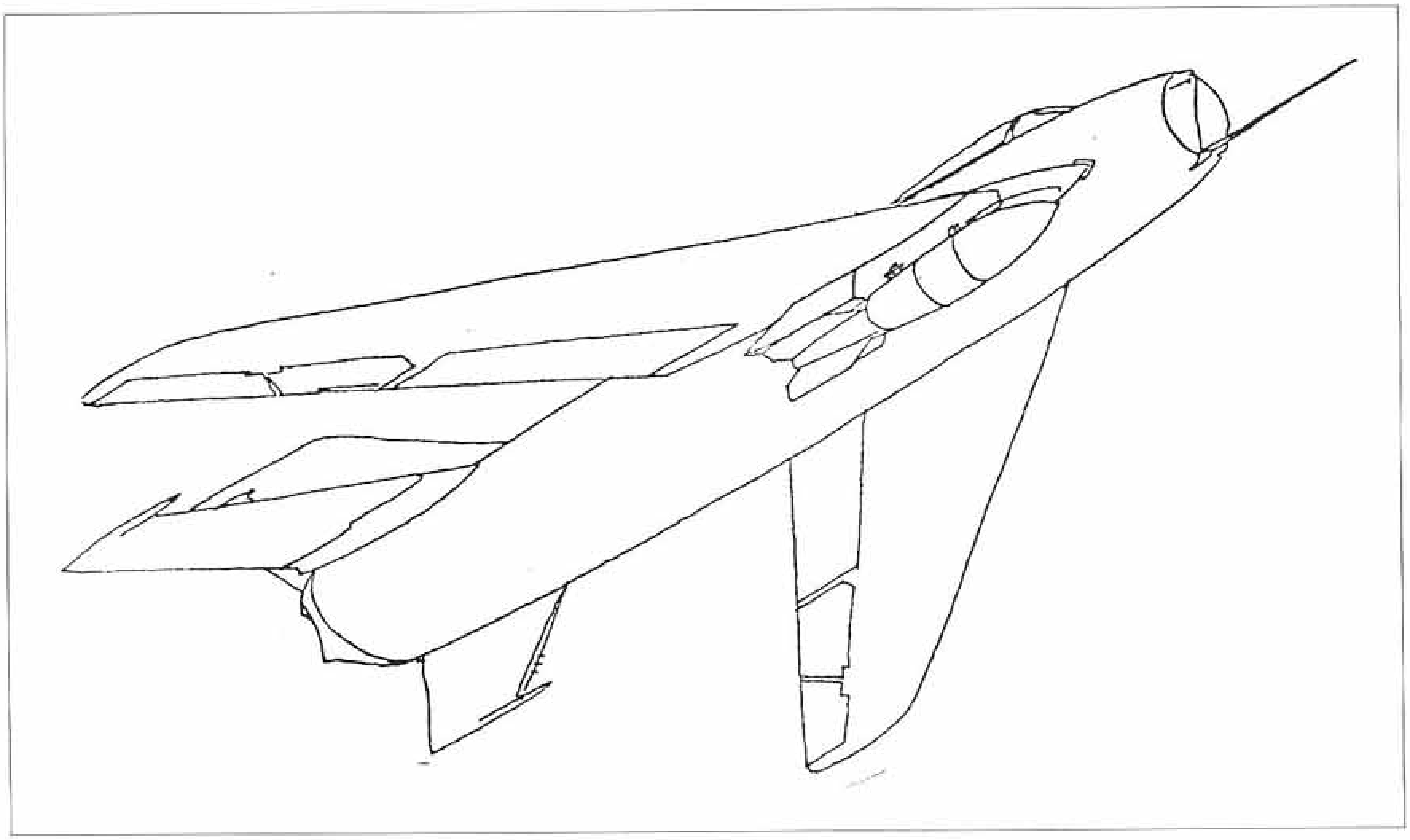
MiG-19S.



MiG-19S: 1, PVD; 2, inlet; 3, S-13 camera; 4, vhf transmitter; 5, vhf receiver; 6, battery; 7, radar altimeter (see 31); 8, ASP-5M sight; 9, instrument panel; 10, ejection seat; 11, vhf antenna; 12, upper tank; 13, RD-9B-811 engine; 14, Bariy-M *antenna; 15, oil tanks; 16, aft airbrake; 17, fuel filler; 18, RWR amplifier; 19, anti-flutter mass; 20, stabilator; 21, bumper; 22, parabrake box; 23, aft tank; 24, ventral fin; 25, left main undercarriage; 26, drop tank; 27, hydraulic cylinder; 28, left main undercarriage door; 29, forward airbrake; 30, left gun magazine; 31, RV-2 antenna; 32, air bottle; 33, left NR-30 gun; 34, retractable landing light; 35, nose undercarriage door; 36, nose undercarriage; 37, taxi light.*

15), the under-fuselage airbrake (hinged to 12 and extending to 14) and the engine mounts (a steady at 15 and the main pickups at 20). The cockpit had a windscreen 64mm thick, an electrically powered canopy jettisonable from any position, a 10mm front armour plate, 16mm armour at Frame 7 and a 25mm armoured headrest serving also as a crash pylon.

The rear fuselage contained three locating links for the long jetpipes and afterburners. The side airbrakes were hinged to Frame 23, extended back to Frame 25 and opened diagonally down



SM-9/9 with nuclear bomb. This project was never built.

to 25°. On the left underneath between Frames 30 and 33 was the container for the PT-19 braking parachute. Under the jetpipes were unprotected Tanks 3 (180 litres, 39.6gal) and 4 (175 litres, 38.5gal). Underneath was the 0.54sq m (5.8sq ft) strake, while above the engines were the hydraulic systems and oil tanks.

Track was 4.156m (13ft 7⅝in), wheelbase 4.398m (14ft 5⅛in) and tyre pressures 10kg/sq cm (142lb/sq in) for the mainwheels and 6kg/sq cm (85.3lb/sq in) for the nosewheel. The hydraulics and flight controls have been described. The pneumatic system provided cockpit pressurization, main and emergency wheel braking, emergency landing-gear extension and flap operation, windscreen and canopy de-icing, canopy sealing and emergency jettison, charging and firing of the guns, control of the crossfeed fuel valves and release and jettison of the braking parachute. The electrical system comprised 28V d.c., with a 12SAM-28 battery. Oxygen was provided by a KP-30 system, with four 3lit bottles. Avionics included RSIU-4, SRD-1M (first batch), SRD-3M (most) or SRD-5 (final batches from Novosibirsk), RV-2, OSP-48 and (not previously described) the ARK-4 *Amur* or ARK-5 radio compass, MRK-48P marker receiver, SRO-1 *Bariy*-M IFF and *Sirena*-2 radar warning receiver. The combat camera was the S-13 or, later, AKS-5. The sight was the ASP-5N-V3. Armament has been described, except that in most series aircraft the fuselage gun had 60 rounds and the wing guns 70.

The MiG-19S served the VVS and IA-PVO in natural metal finish, with wheels painted green and all inner surfaces (landing-gear wells and cockpit) grey. Aircraft were exported to – in chronological order – Czechoslovakia (which made 103 under licence as the S-105), Bulgaria, the German Democratic Republic, Egypt, Syria, Iraq, North Korea, North Vietnam, Cuba, Indonesia and, in 1965, Afghanistan. Chinese versions are described later. The ASCC name was 'Farmer-C'.

Dimensions as MiG-19.

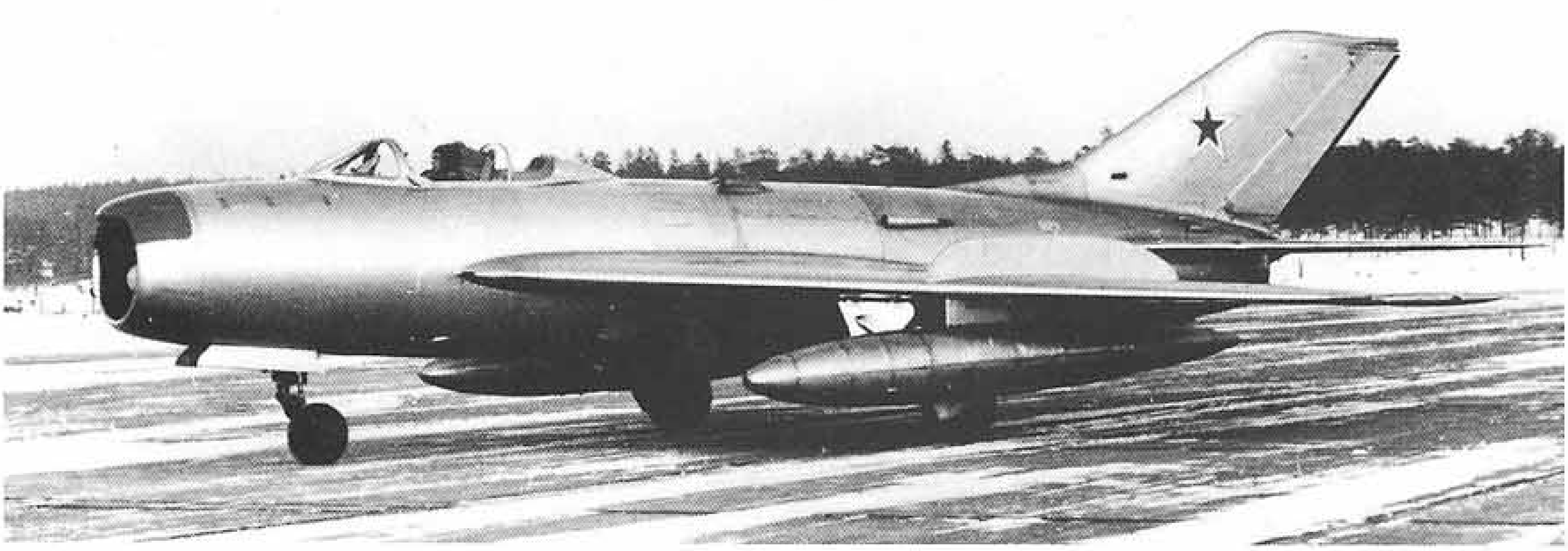
Weight empty (first series) 5,172kg (11,402lb), (most) 5,455kg (12,026lb); loaded weight (clean) 7,560kg (16,667lb), (maximum, first series) 8,650kg (19,070lb), (most) 8,832kg (19,471lb).

Performance identical to MiG-19; additional data: range at high altitude (internal fuel) 1,390km (864 miles), (two 760lit tanks) 2,200km (1,367 miles); takeoff run (afterburner) 515m (1,690ft), (dry) 650m (2,133ft); landing speed 235km/h (146mph); landing run 1,090m (3,576ft), (maximum braking on three wheels) 890m (2,920ft), (with parabrake) 610m (2,000ft); g limits, (clean) 8.5, (empty drop tanks) 6.5, (full tanks) 5.

MiG-19P, SM-7

Ministerial Decree No. 2181-887 of 15 August 1953 also ordered the OKB to develop a supersonic air-defence interceptor able to operate at night or in bad weather. The OKB named the prototype SM-7/1. Various documents, including a detailed account by A V Fedorchenko, A V Kotlobovskiy and A V Khaustov, insist that, to save time, the OKB decided to produce it by modifying the SM-9/1. This is impossible to reconcile with the known history of the SM-9/1. In fact, the SM-7/1 was built at the same time as the SM-9/1, and the airframes were very similar. For example, the horizontal tail was of SM-9/1 type, and there was no dorsal spine or belly airbrake.

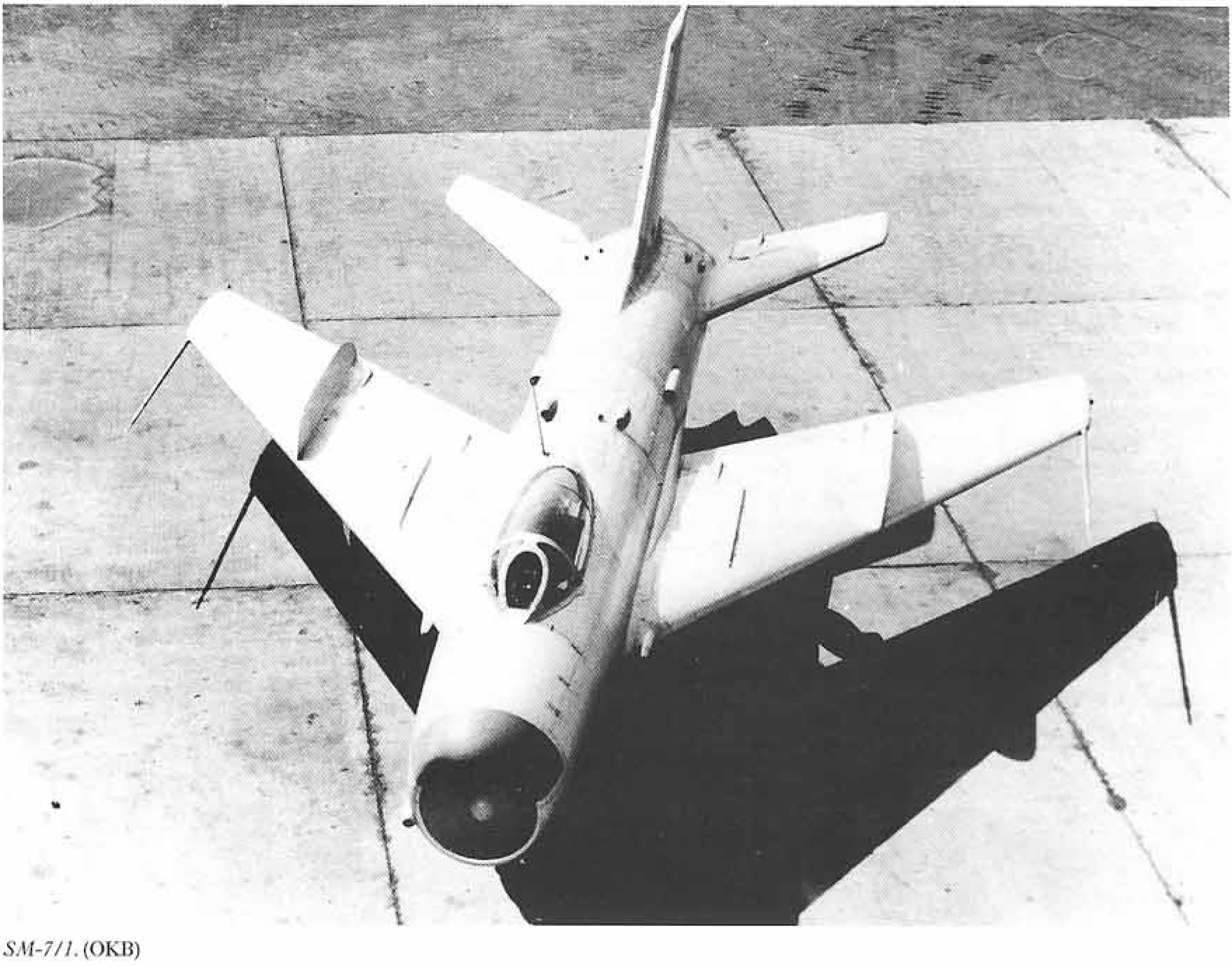
Ahead of the original Frame 7 at the back of the cockpit the fuselage was extended by two frames, adding 0.36m (14.2in). The structure was redesigned with the skin stiffened by 28 light transverse rings, which allowed the engine air ducts to be moved further apart, giving greater width in the cockpit. The SRD-1M ranging unit was replaced by the RP-5 *Izumrud* radar, with its two antennas



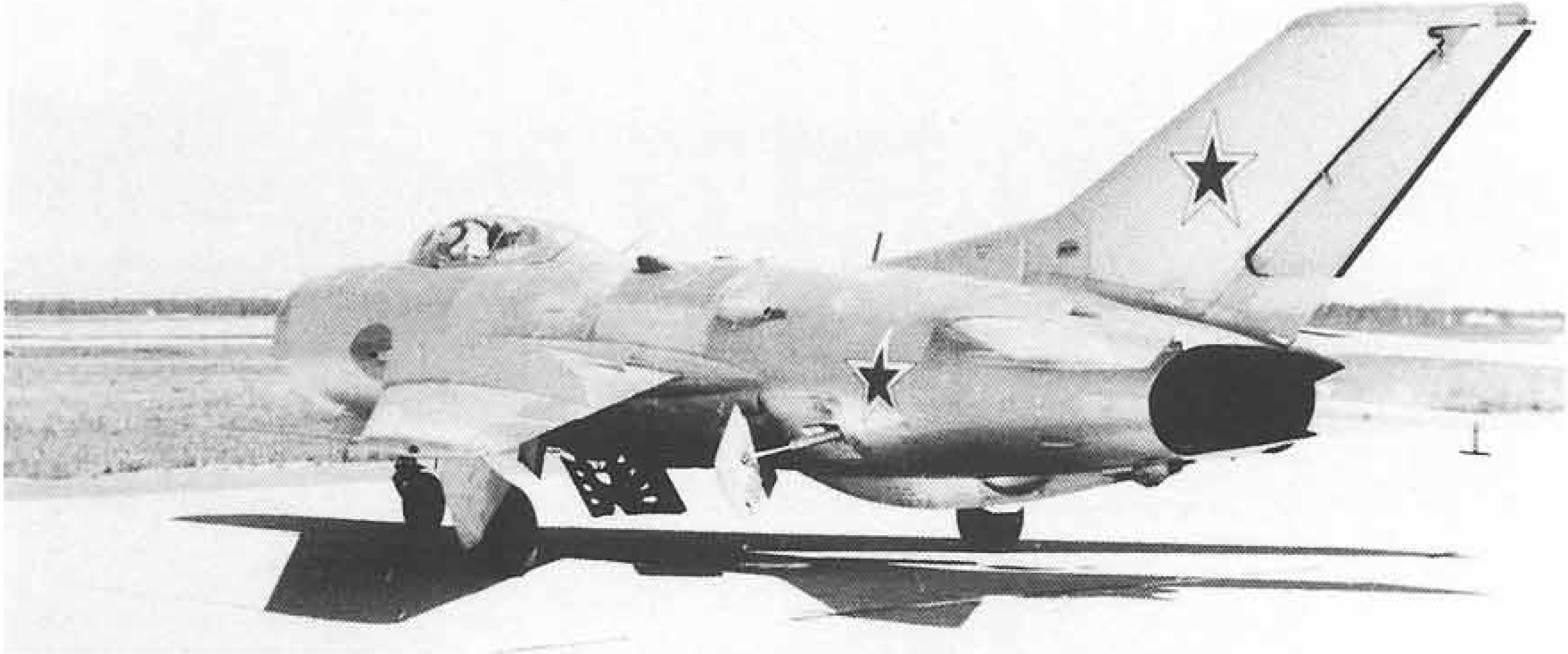
SM-7/1. (OKB)

arranged as in interceptor MiG-17s, the AR-18-1 scanning antenna being in the extended upper intake lip and the AR-18-16 dish for target tracking and ranging being in a central bullet fairing. Against a 16sq m (172sq ft) target the effective detection range was 12km (7.5 miles), and tracking range 2km (1¼ miles). The radar boxes were installed in the extended forward fuselage together with the rearranged radio (which was changed to RSIU-4), six being in the space previously occupied by the fuselage NR-23 gun and its magazine. Published descriptions include retention of racks for ORO-57, ARS-57 or RO-57-8 launchers for eight or sixteen S-5 rockets of 57mm calibre. The implication is that these were used to bring down enemy bombers, but for practical purposes the only armament remained two NR-23 with 120 rounds each.

The nose air-data boom was omitted and the wingtip booms retained, together with the RV-2 antenna under the starboard outer wing. Two of the



SM-7/1. (OKB)



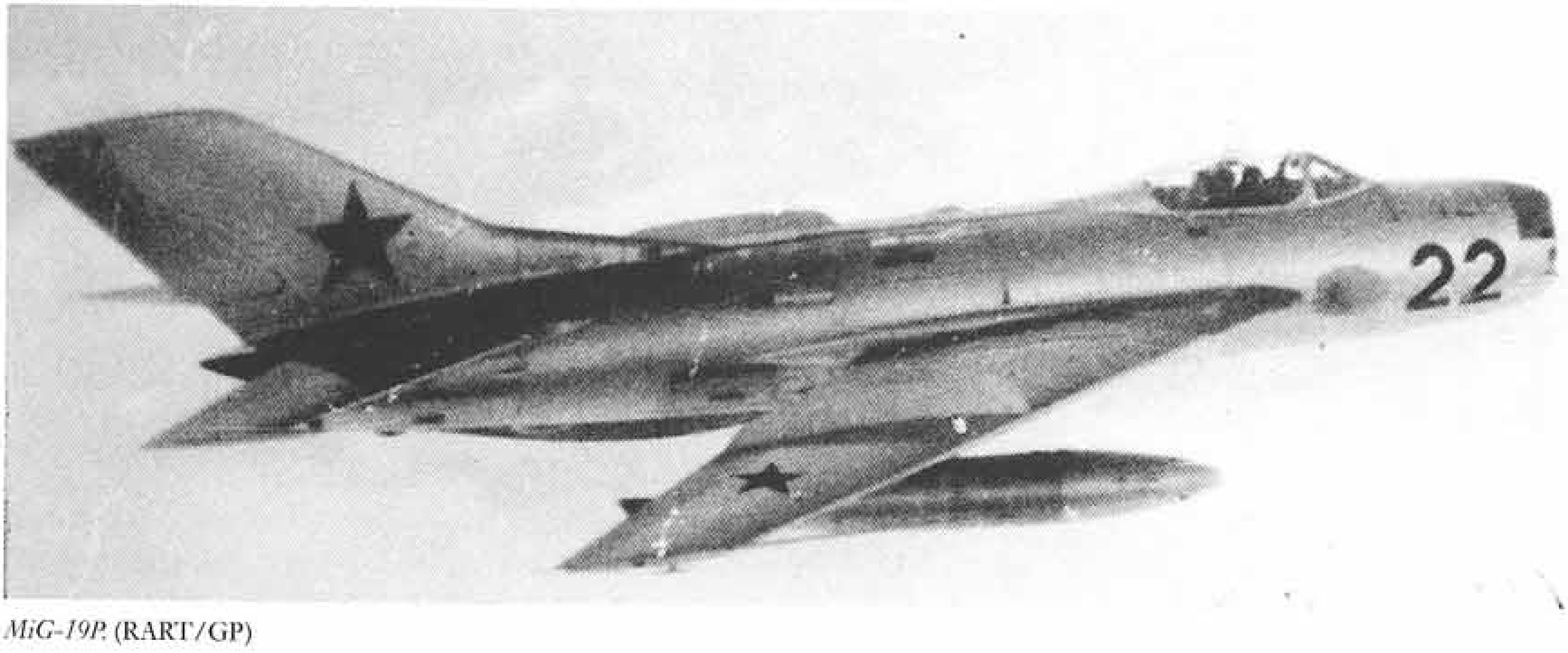
SM-7/2. (RART/GP)

engine-bay cooling inlets were omitted, the top of the fin was modified to incorporate the aft-facing antenna of a *Sirena*-2 radar warning receiver, the KP-30 oxygen system was augmented by two extra bottles to make five (total 10lit), and an S-13 camera was added on the right of the nose. Pilot view was impaired by the radar visor and the longer nose.

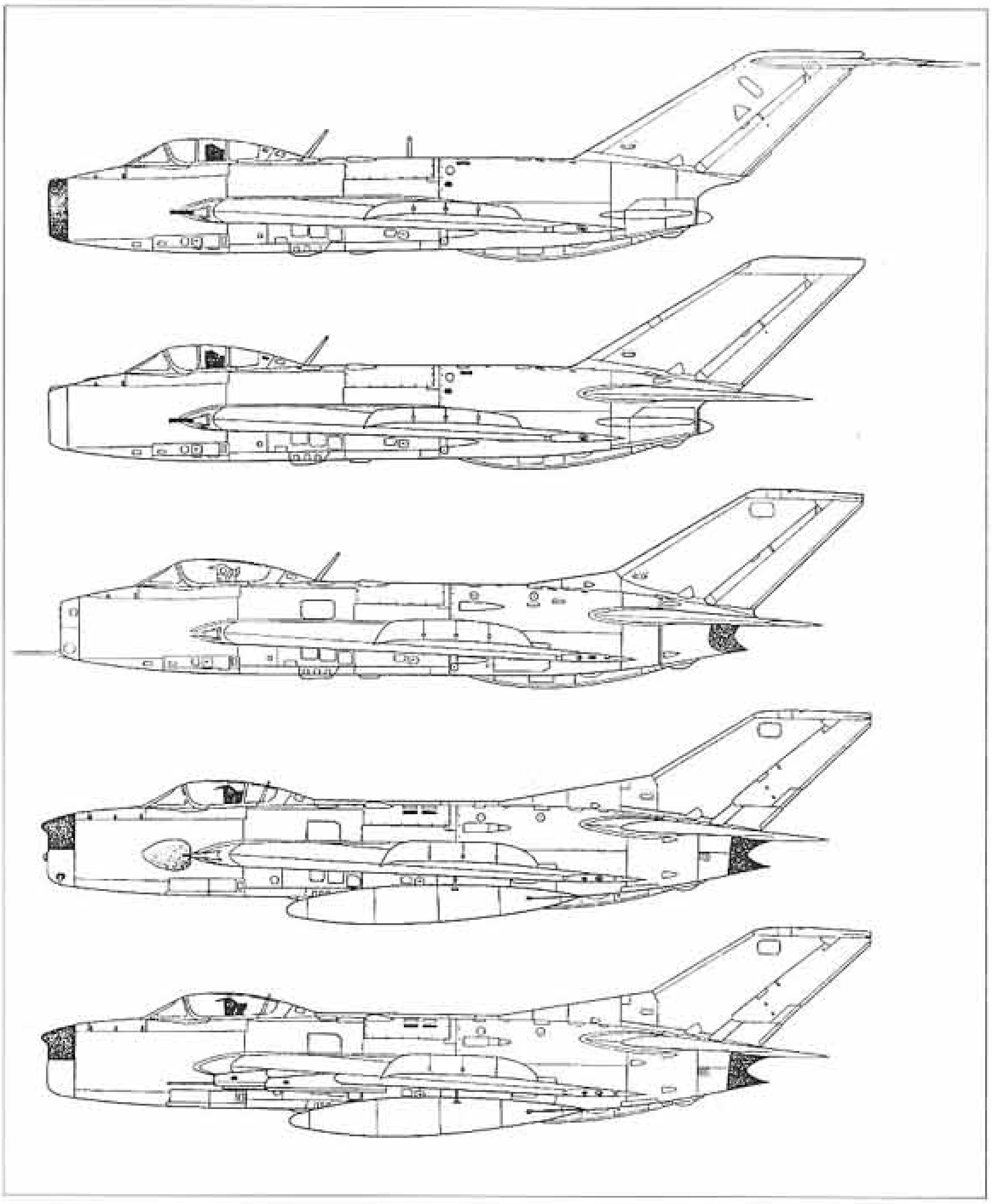
The OKB assigned LII-MAP pilot V A Nefyodov to this programme, and he began the SM-7/1 flight-test programme on 28 August 1954 – at which time the SM-9/1 was still on factory test, so it could hardly have also existed as the SM-7/1 – completing it on 15 December. In 1955 the OKB built two additional prototypes from scratch, SM-7/2 and -7/3. These had most of the new features of the SM-9/3, including the slab *stabilizator*, three airbrakes and a larger dorsal fin (on 7/3 faired into a spine). The flight-control rods from the stick remained beneath the cockpit floor before passing up the rear pressure bulkhead to run along the top of the fuselage. In the SM-7/2 and subsequent interceptors, the tail control rods were carried above the fuselage inside the spine, as in the MiG-19S.

The SM-7 test programme was punctuated by various problems, including many engine difficulties and a braking parachute streamed in flight. NII-VVS pilot Beregovoy suffered a jammed stick and had to fly on the electric standby worm-wheel screwjack. He was told to eject, but managed to bring off a safe landing. Other NII-VVS pilots included S A Mikoyan, A S Solodovnikov, V G Ivanov and N P Zakharov.

From November 1955 the Gor'kiy factory built about two hundred MiG-19P gun-armed interceptors for the IA-PVO, as well as (from late 1957) twenty-seven for Czechoslovakia, twelve for Poland and fifteen for Romania. In 1966 Bulgaria took over surviving MiG-19Ps from Poland. The series aircraft was distinguished by a more pointed AR-18-16 radome. Some accounts state that the armament was two NR-30s; in fact, the two NR-23 guns were retained, each with 140 rounds. All were fitted with RP-5 *Izumrud* radar, and with either of two types of GCI (ground control of interception) receiver. Those with the *Gorizont*-1 (horizon) were designated **MiG-19PG**, while those fitted with *Lazur* (azure) became the **MiG-19PL**. All but the first production



MiG-19P. (RART/GP)



From the top: SM-2/1; SM-2/1 modified; MiG-19; MiG-19P; MiG-19PM.

series had a rudder trimmer, and the air-data boom was removed from the port wingtip. In 1960 survivors were modified in IA-PVO repair factories to launch two R-3S (K-13) missiles, and a few were brought up to MiG-19PM standard. The MiG-19P received the ASCC name 'Farmer-B'.

Dimensions unchanged, except overall length 13.02m (42ft 8⅝in), fuselage length 10.71m (35ft 1¼in).

Weight empty 5,468kg (12,055lb); internal fuel 1,700kg (3,748lb); weight loaded 7,384kg (16,279lb), with two tanks 8,738kg (19,264lb), maximum 9,100kg (20,062lb).

Maximum speed 1,180km/h (733mph) at sea level, 1,384km/h (860mph, Mach 1.3) at 9,800m (32,152ft); climb, lighting afterburner at 5,000m (16,404ft) 1.85min to 10,000m (32,808ft), 3.8min to 15,000m (49,213ft); service ceiling (in afterburner) 17,600m (57,745ft), (with K-13 missiles) 17,250m (56,595ft), (maximum dry thrust) 16,150m (52,986ft); range 1,910km (1,187 miles), (two tanks) 2,318km (1,440 miles); design load factor 7.95.

MiG-19PM, SM-7/M

Having been developed from 1950 by PD Grushin's OKB-2 bureau, the S-1-U and S-2-U missile systems were already familiar to the Mikoyan OKB from their use on the MiG-17PFU. It is remarkable that nothing was done to fit missiles to the MiG-19 until late 1955. The first missile-armed prototype, designated SP-7/M (*modernizirovannyi*) was completed on 7 January 1956.

The airframe was based on that of the SM-7/1, with elevators, two wingtip probes and no spine. Indeed, whether or not the SM-7/1 was SM-9/1 rebuilt, there seems little doubt that the same aircraft was converted into the SM-7/M. The outboard hardpoints were retained, for tanks, but the inboard attachments behind the main landing gear was removed, as were the gun installations. In their place two APU-4 launch rails were installed under each inboard leading edge, each matched to a K-5M radar-guided missile (designated RS-2U in its production form, or RS-2US for the Su-9).

The radar was replaced by the RP-2U *Izumrud*-2, with antennas giving search over a flattened cone measuring ± 60° left/right and from +26° to –14° vertically, as in the MiG-17PFU. The inlet was made deeper, and the ranging antenna had a larger dielectric area in the upper lip. Tracking range was almost doubled at 3.5km (11,480ft), but this short distance was still a serious limitation, especially as the missile had an effective range of 6km. The sight was changed to the ASP-5N-VU, to which was fed target range and coordinates in azimuth and elevation. As in the MiG-17PFU the pilot had a PUVS-52 missile inert/active control panel, and buttons on the stick grip to fire the missiles, replacing gun triggers. Just as the MiG-17P could carry rocket pods, so could the SM-7/M pylons have interfaces for the large ARS-160 or ARS-212M unguided rockets, though such weapons were hardly appropriate to an interceptor and their repeated mention is puzzling. In place of the DGMK gyrocompass a GIK-1 Earth-inductor compass was fitted, with the sensor in the fin.

Sedov was assigned to the factory test programme, which took about a year. The SM-7/M was handed over for NII-VVS testing in January 1957. By this time the new-build SM-7/2M was also flying. This had the slab tailplane, dorsal spine and air-data probe on the starboard wingtip only. NII-VVS pilot on the SM-7/2M was S A Mikoyan. Compared with earlier MiG-19s, the missile-armed aircraft had poorer performance and suffered from a higher incidence of malfunctions. It was not until 14–23 October 1957 that SM-7/2M was tested with live missiles, by which time most of the series aircraft had been delivered.

A production order had been placed in 1956, the series aircraft being designated MiG-19PM. When fitted with *Lazur* the designation was **MiG-19PML**. Only the Gor'kiy factory was involved and the total production run was only about 260. The last MiG-19PM was delivered in December 1957 (Gor'kiy thereafter building the MiG-21 and Novosibirsk the Su-9). In 1959–60 a total of

MiG-19PM. (RART/GP)

135 MiG-19PM interceptors were exported: thirty-three to Czechoslovakia, twelve to the German Democratic Republic, twelve to Hungary, thirteen to Poland (in 1966–67 passed to Bulgaria), forty-five to Romania, fifteen to Albania and five (dismantled) to China.

Total Soviet production of all versions of the MiG-19 was a mere 2,069, excluding prototypes. ASCC name for the MiG-19PM was 'Farmer-D'.

Dimensions as MiG-19P.

Weight empty 5,660kg (12,478lb); internal fuel 1,700kg (3,748lb); weight loaded 7,880kg (17,372lb); maximum weight in service (tanks limited to 400lit) 8,464kg (18,660lb); maximum permissible 9,400kg (20,723lb).

Maximum speed at 5,000m (16,404ft) 1,100km/h (684mph); maximum speed 1,250km/h (777mph, Mach 1.177) at 10,000m (32,808ft), climb to 15,000m (49,210ft) 4.8min, or 7.2min in maximum dry thrust; service ceiling 16,700m (54,790ft); range 1,000km (621 miles), with two 400lit tanks 1,415km (879 miles); takeoff run 900m (2,953ft); landing speed 235km/h (146mph); landing run 890m (2,920ft), using wheel brakes only.

MiG-19SV, SM-9V

In 1955 invasions of Soviet airspace by Western reconnaissance aircraft and unmanned balloons were becoming more and more frequent, and the Lockheed U-2 promised a further, increased threat. In August 1955 the OKB was told to launch an urgent programme for an ultrahigh-altitude interceptor, and to deliver one hundred as soon as possible. Project director was V A Arkhipov. This was to be an interim solution while purpose-designed interceptors and SAMs were produced.

The resulting SM-9V (*vysotnyi*, height) was produced in two months. The most significant change was to extend the wings, accepting a reduction in design load factor. The increase in empty weight was reduced by 230kg (507lb) by removing the two wing-mounted guns (leaving just the single NR-30 in the fuselage), seat armour, braking parachute and RV-2 radar altimeter. The engines were the newly developed RD-9BF (later replaced by the BF2 version) in which raising the turbine gas temperature to 730°C increased maximum afterburning thrust to 3,300kg (7,275lb). Four extra air scoops were added above the fuselage to cool the engine bays. The flaps were arranged to be extended to a new setting at high altitudes; some OKB documents give this as 8°, other sources quote 10° and 12°. Despite the saving of 230kg the published empty weight is nevertheless much heavier than that of the MiG-19S, and this figure may be an error.

In addition, special flying clothing was developed, though this took longer. The VKK-2 partial-pressure suit and KKO-1 pressure breathing system were already coming into use, and for use at extreme altitudes the VSS-04 full-pressure suit and GSh helmet were developed. The OKB played a role in this development.

No date is known for the first flight of the SM-9V, but factory testing by Mosolov and Nefyodov is known to have been trouble-free. At modest speeds the aircraft handled better than the MiG-19S, though it failed to achieve the required service ceiling of 20,000m (65,617ft). The number built was much less than the originally requested one hundred. The MiG-19SV was issued to IA-PVO regiments at strategic locations. On 6 December 1956 NII-VVS pilot N I Korovushkin made a zoom to 20,740m (68,045ft). The OKB then studied adding an Isaev rocket engine. The SV was unknown in the West.

Span 10.3m (33ft 9½in); length 14.64m (48ft 0⅜in), (omitting air-data boom) 12.54m as before; wing area 27sq m (290.6sq ft).

Weight empty given as 5,580kg (12,302lb); weight loaded 7,250kg (15,983lb).

Maximum speed 1,572km/h (977mph, Mach 1.48) at 10,000m (32,808ft); service ceiling given as 18,500m (60,696ft) and also as 19,000m (62,336ft); thrust/weight ratio at gross weight 0.91; load factor 7.2.

MiG-19R, SM-9R

From 1954 several aircraft were factory tested with AFA-39 cameras or with the BA-40 and the MAG-9 voice recorder. A small number of MiG-19R series aircraft were built.

The MiG OKB never produced a dual-control MiG-19. Documents describing such an aircraft are fiction.

Experimental MiG-19s

Over fifty aircraft, mostly MiG-19S series aircraft in the 400–450 range, were modified for use in various research programmes. In 1954 all series aircraft changed from the KT-37 mainwheel to the KT-61 with a disc brake, replaced in 1957 by the KT-87 with a multidisc brake on a stronger leg. The nosewheel brake was also changed to a disc, and most serving aircraft were modified. MiG-19 and MiG-19S aircraft were used to develop the BK-65 astrocompass repeater, *Svod* (vault) range/bearing beacon-homing system, the *Ilem* (elm) direction finder (trying five antenna positions), the NI-50IM ground-position computer and the RUP-4 and APB-1 blind-landing systems.

SM-10

In May 1954 a ministerial decree ordered development of a MiG-19 equipped for air refuelling from a Tupolev Tu-4 tanker. Series MiG-19 callsign '415' was modified by a team led by A I Komissarov, copying British technology in fitting a probe but locating it above the port wingtip. Considerable modification was needed to enable the incoming fuel to pass at 1,000lit (220gal)/min along the wing, past one-way valves, to fill all available tankage. The pilot's oxygen supply was increased to 18 litres, sufficient for a ten-hour mission with two refuellings, and both the receiver and tanker were fitted with special lighting to assist night refuelling.

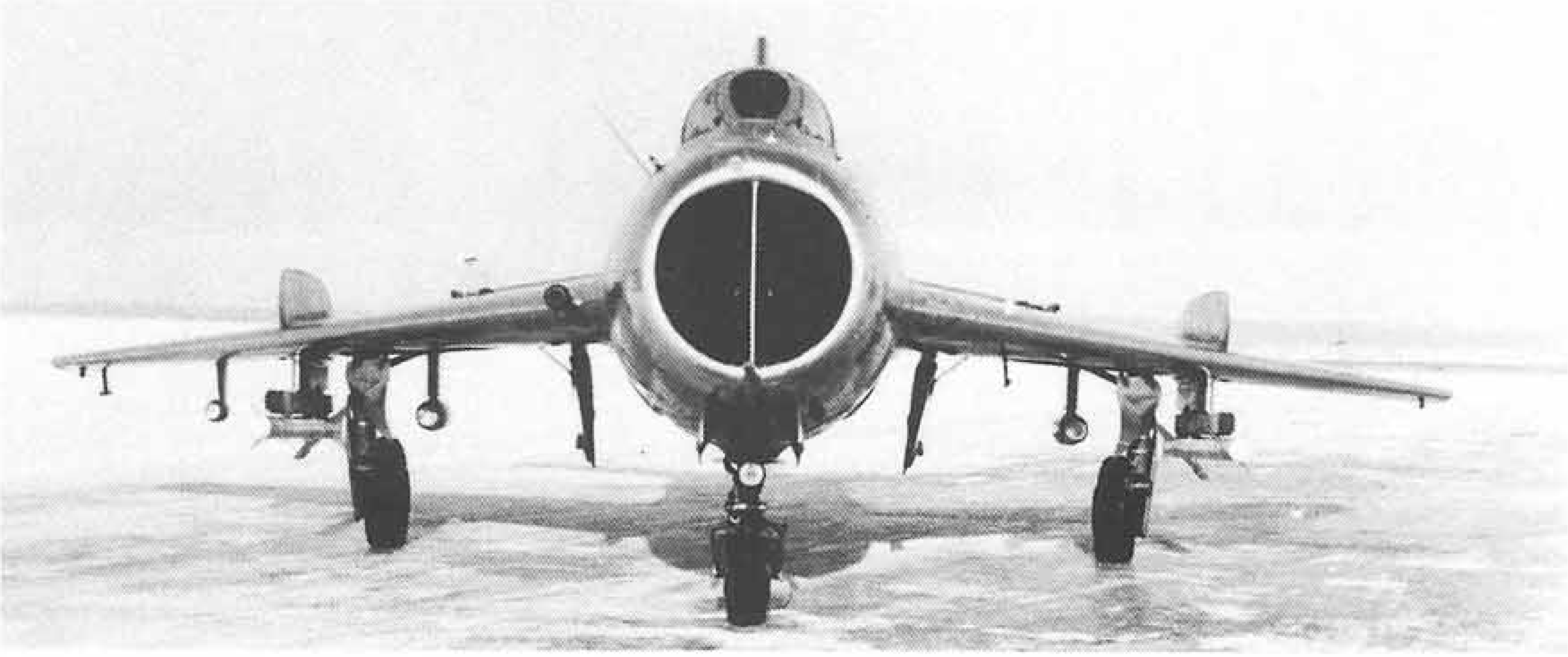
Nefyodov (OKB) and V N Pronyakin (LII-MAP) completed successful dry and then wet contacts from September 1955, but the production system was unable to be funded at that time. (In 1963 the Tu-16N did go into service, but for later receiver aircraft.)

MiG-19, C/s 10

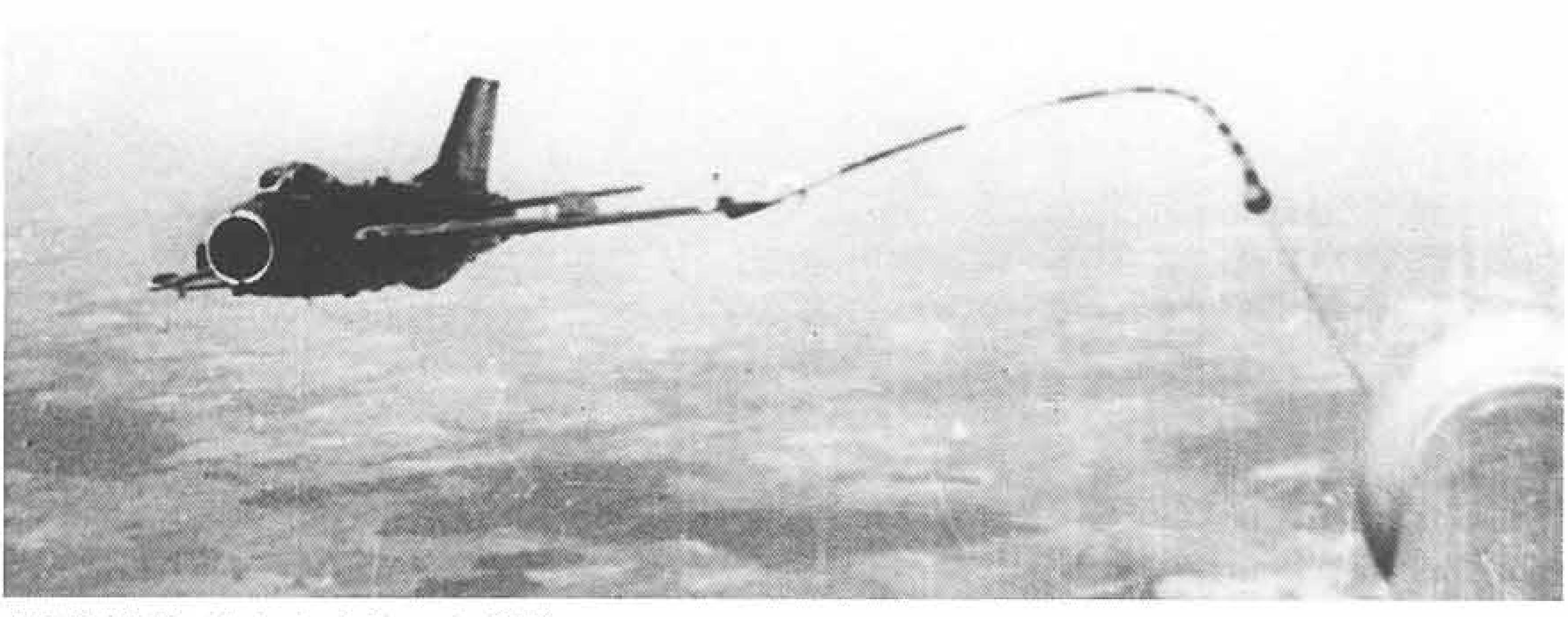
In 1956 this aircraft made prolonged trials behind the prototype Ilyushin Il-28 tanker to test reception at four probes, one on the leading edge of the port wing, one above the starboard wing, one at the bottom of the nose and the fourth at the top left of the nose. These probes, and the onboard fuel system, were designed for a higher transfer rate than the SM-10.

SM-21

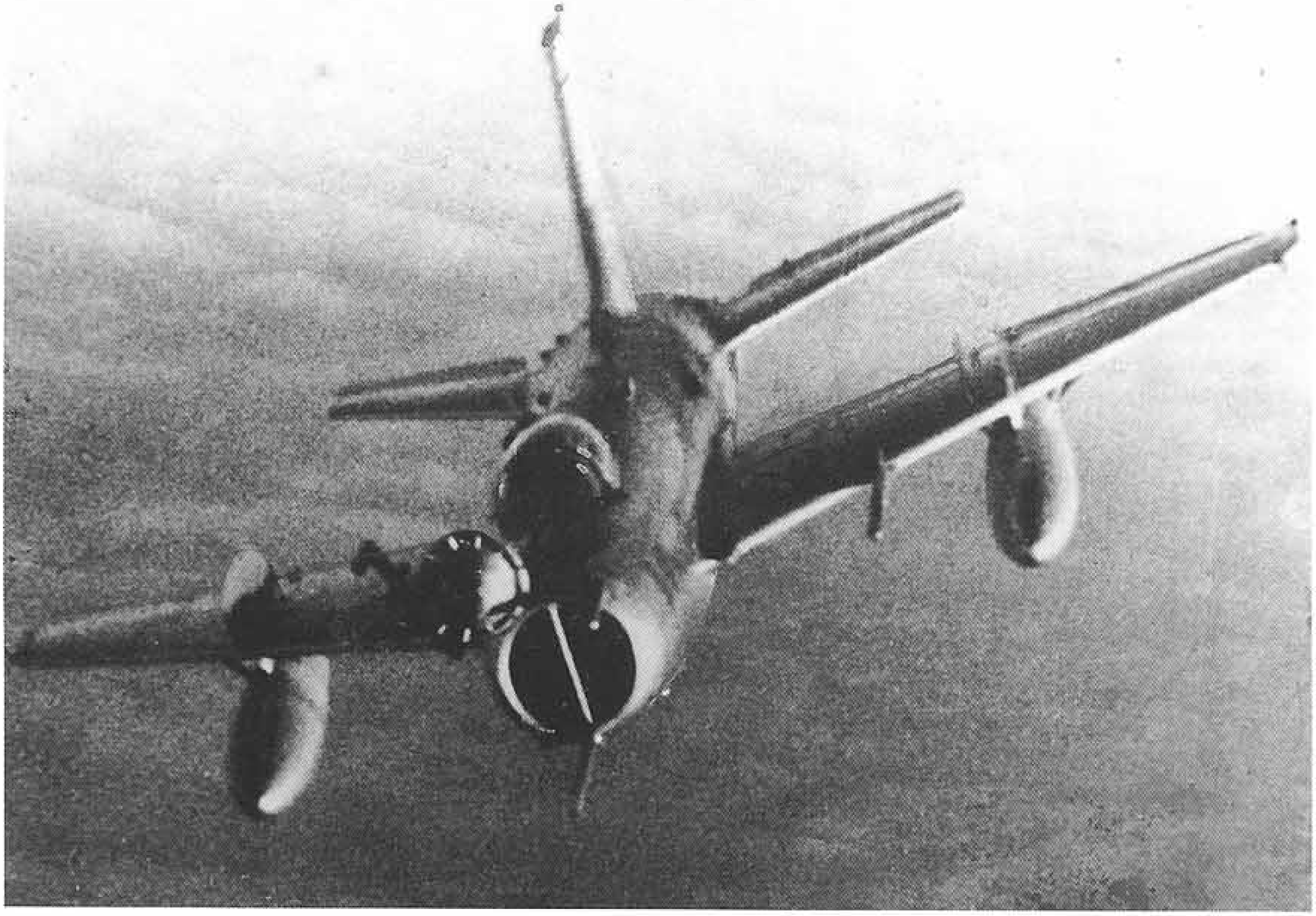
In 1955 MiG-19S callsign '406' was used with this designation for firing trials with the S-21 rocket of 210mm calibre. They were fired from single pylons.



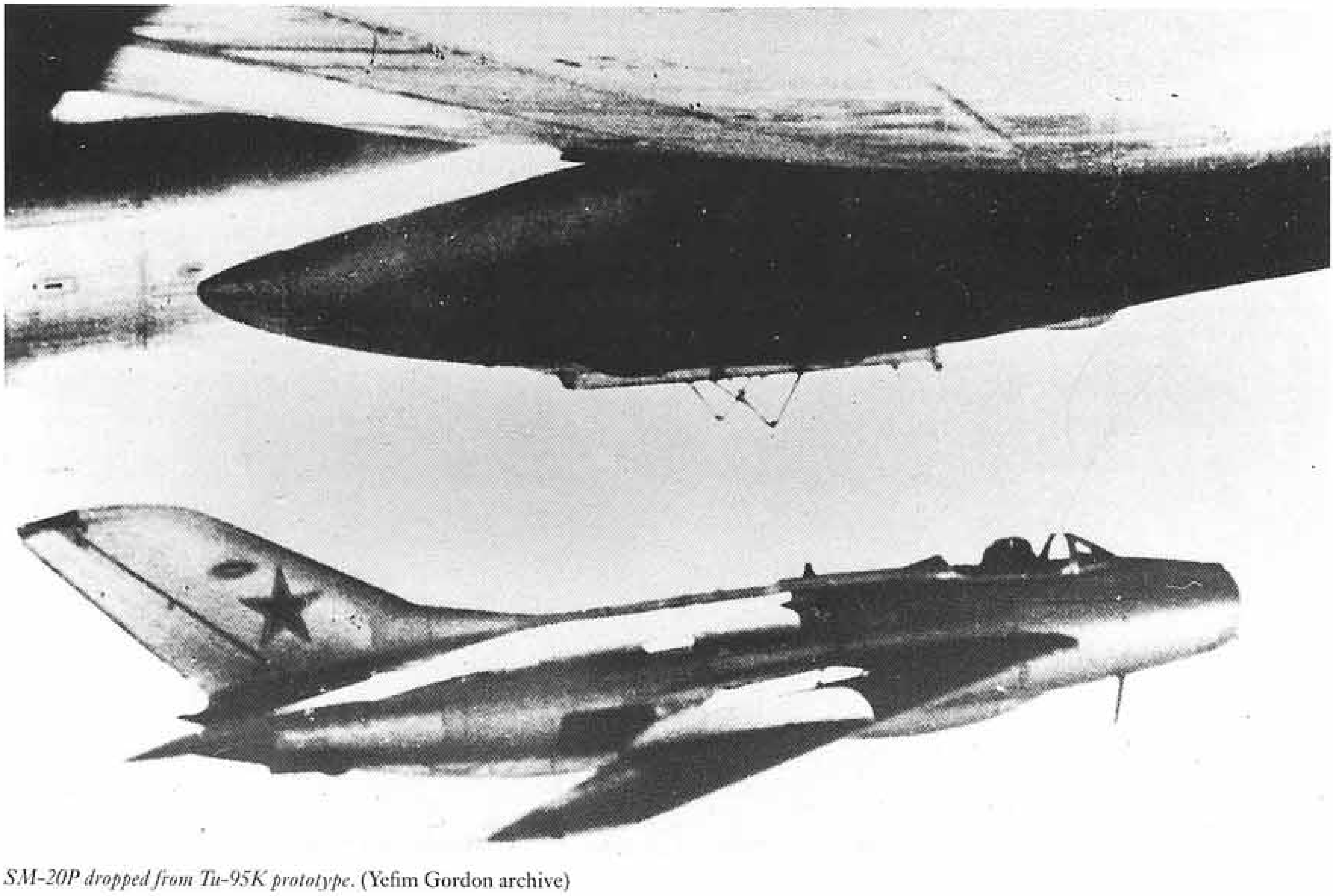
MiG-19S with K-13 missiles (see also SM-9/3T). (RART/GP)



MiG-19, SM-10, with wingtip refuelling probe. (OKB)



MiG-19 trials aircraft with four inflight-refuelling probes. (Yefim Gordon archive)



SM-20P dropped from Tu-95K prototype. (Yefim Gordon archive)

SM-11

This designation applied to a MiG-19P used in 1956 to test the *Yastreb* (hawk) FLIR (forward-looking infrared) sensor.

SM-20, SM-20P

The SM-20 was a MiG-19S modified as a pilotless aircraft to test the guidance system of the OKB's Kh-20 cruise missile (*see* 'Guided Missiles'). It was fitted with the complete on-board guidance system, using a whip antenna under the nose, a position beacon, radar reflector and other equipment, as well as forged suspension lugs recessed into the fuselage on each side at the centre of gravity. It was carried under a Tu-95K prototype, with steadying pads which butted against the fighter canopy. On reaching the drop altitude the test manager in the parent aircraft started the SM-20's engines and released. Tests began in October 1956.

The SM-20P may have been the same aircraft, but chronologically it followed the SM-20. P stood for piloted. This aircraft had the engine fuel systems modified to ensure vaporization of the fuel on entering the combustion chambers. This facilitated engine starting at high altitudes, which had caused difficulties.

SM-K/1, SM-K/2

These modified MiG-19S testbeds were fitted with the guidance system of the OKB's K-22 supersonic cruise missile. They began this test programme in late 1957.

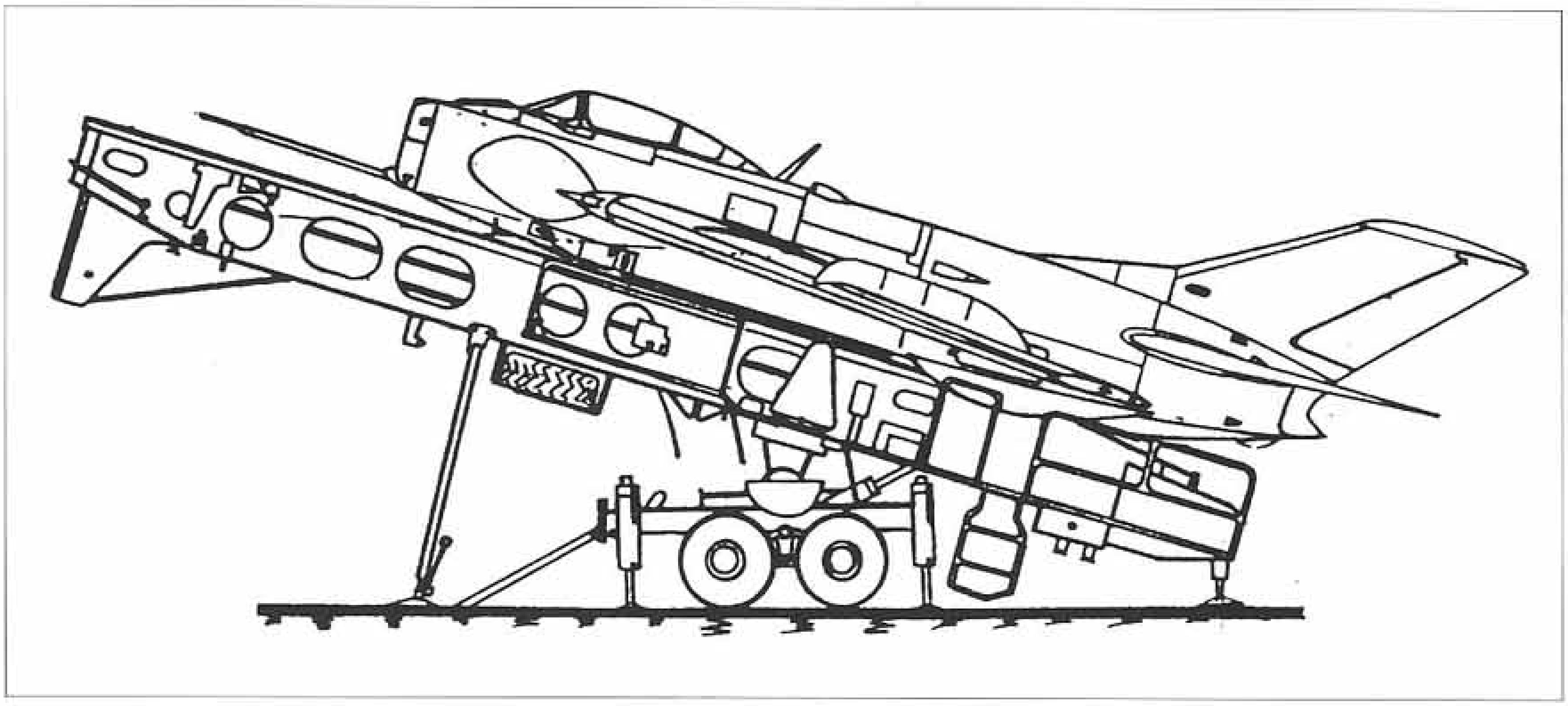
SL-19

This aircraft, a MiG-19, was used at the LII-MAP to help develop ski landing gear. Both wheelbase and track could be altered.

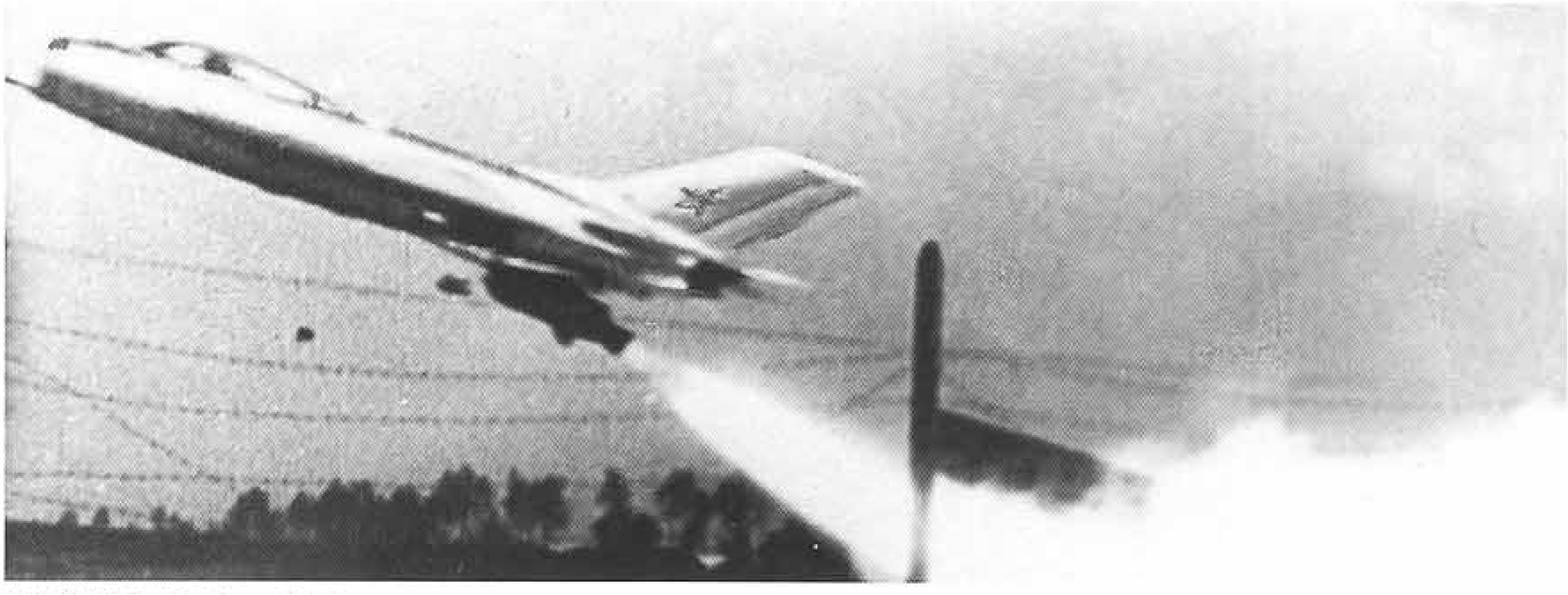
SM-30

From April 1955 the OKB worked on ZELL (zero-length launching). The intention was to base interceptors in remote but threatened locations such as Novaya Zemlya, and launch them with a powerful rocket. Gurevich managed the programme, with A G Agronik in charge of testing.

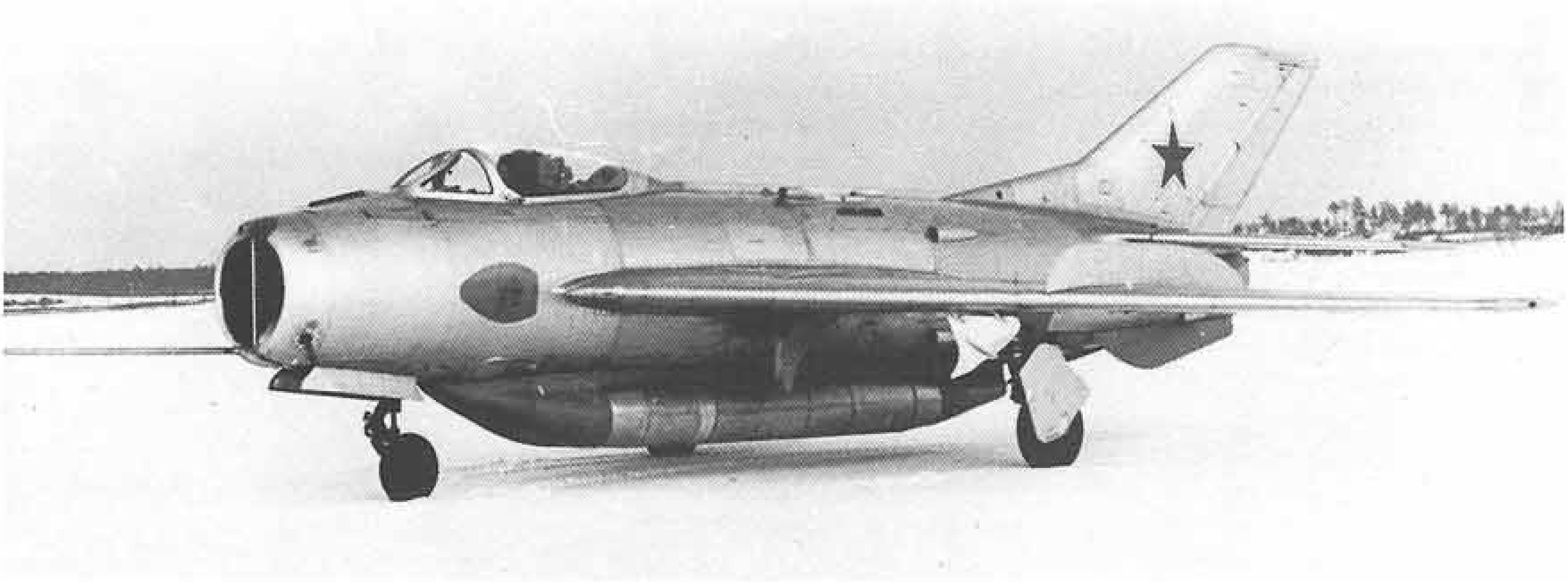
MiG-19 and MiG-19S aircraft were modified with stronger fuselage frames and tank mountings, extra fuselage/wing attachments, a stiffened inlet duct, a pilot headrest which prevented head movement, two diagonal underfuselage strakes replacing that on the centreline, and fitting a flight-control lock which released after three seconds of ballistic flight. The aircraft



SM-30 on transporter/erector.



SM-30. (Yefim Gordon archive)



SM-50. (OKB)

were fitted with a PRD-22 solid motor providing a peak thrust of 40 tons (88,183lb) for 2.5sec, giving peak acceleration of 4.5g. This was mounted under the rear fuselage, and the aircraft was then placed by crane on a PU-30 off-road transporter from which it was fired at an inclination of 15°.

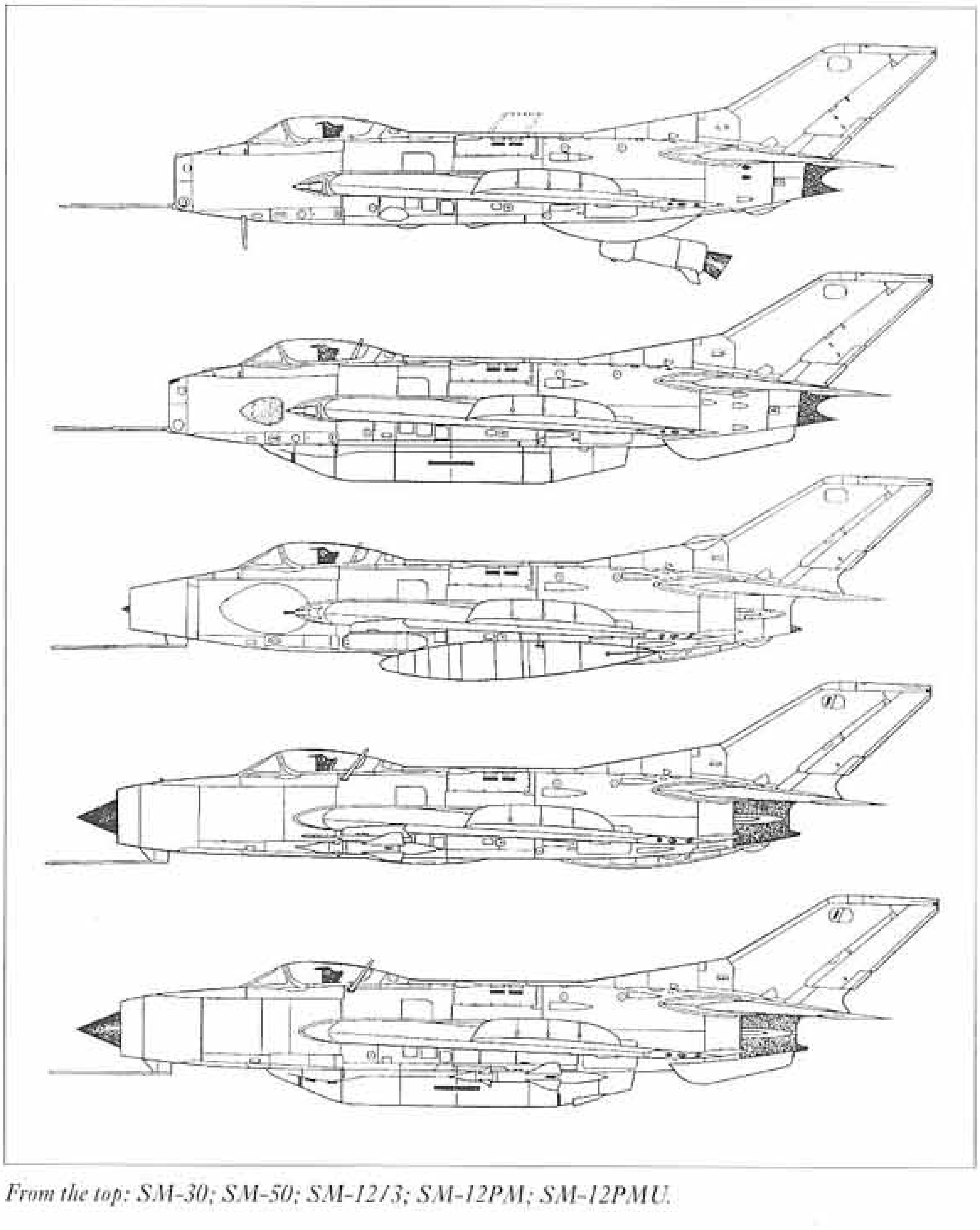
One launch without a pilot was followed from 13 April 1957 by eleven manned launches by G Shiyanov, followed by Yu A Anokhin and many other test pilots. By 1958 landings using overlarge parachutes and hydraulically braked arrester cables brought down landing distance to 120m (394ft), but the system never went into service.

MiG-19SU, SM-50

These testbeds were fitted with a jettisonable booster rocket pack under the fuselage. The objective was to decrease the time taken to climb to the level of hostile bombers, and the SM-50s and their successors were assigned to the task of developing the rocket system.

The rocket was the RU-013, developed by the KB of L S Dushkin. The pilot could select two thrust ratings, which at sea level were 1,300kg (2,866lb) or 3,000kg (6,614lb); the RU-013 is further described in Appendix 1. It was installed in a large U-19 (U for *uskoritel'*, accelerator) pack scabbed under the fuselage. Designed under D D Sevruk, this was constructed at the MiG OKB. Though streamlined, it basically comprised two parallel tubes housing the propellants and turbopump peroxide. It also housed the control system and jettison circuits, with the thrust chamber at the back. The SM-50 was based on a MiG-19S, but fitted with AM-9BM (RD-9BM) engines of variable afterburning thrust. The ventral strake-fin was replaced by two large vertical ventral fins under the centerlines of the engines. The fuselage gun was removed, and a telemetry antenna projected diagonally from the nose.

Chief engineer was Yu N Korolyov (no relation to S P Korolyov) and factory testing was started in December 1957 (after the start of Ye-50 testing) by LII-MAP pilot M M Kotel'nikov. He was joined by OKB pilot Nefyodov. Takeoff weight was 9,000kg (19,841lb), and the rotation speed



From the top: SM-30; SM-50; SM-12/3; SM-12PM; SM-12PMU.

395km/h (245mph). The rocket was usually fired at 17,000m (55,774ft), in bursts of 100 or 67 seconds. The only measured performance was a climb to 20,000m (65,617ft) in 8 minutes, and a level speed of 1,800km/h (1,118mph, Mach 1.695). Range was estimated at 800km (497 miles). Dynamic (zoom) ceiling was put at 24,000m (78,740ft). Five SM-50s were built at Gor'kiy, and these were flown by LII pilots Kotel'nikov and Shcherbakov.

MiG-19PU, SM-51

This aircraft differed in being modified from a MiG-19P, with RP-5 *Izumrud* radar. It was powered by Sorokin R3M-26 turbojets (*see* Appendix 1), each rated at 3,800kg (8,377lb) with maximum afterburner, and the U-19D rocket pack. Unlike the U-19, the U-19D had a control system which enabled the rocket engine to be started and stopped five times in each flight. The SM-51's loaded weight was the same as that of the SM-50.

SM-52, SM-52P

The third rocket-engine testbed differed from the SM-51 in having the *Almaz* (diamond) radar. It was modified into the SM-52P, based on the MiG-19PG with a *Gorizont* link and *Baza*-6 (base) radar ranger.

SM-12

This designation identified a succession of experimental MiG-19S derivatives in which new engines and improved supersonic inlets enabled speed to be dramatically increased. The SM-12/1 was first flown in early 1957. Based on a MiG-19S, its RD-9BF-2 engines were fed by ducts from a new inlet in an extended nose with a sharp circular lip and a large central cone carried in a cut-back vertical splitter. This cone could be hydraulically translated (moved in or out) to adjust the inlet area and shockwave pattern to the flight Mach number. An air-data boom was fitted on each wingtip, the fuselage gun was omitted, the airbrakes were relocated at the extreme end of the fuselage under the tailplanes, and additional engine-bay cooling inlets were fitted.

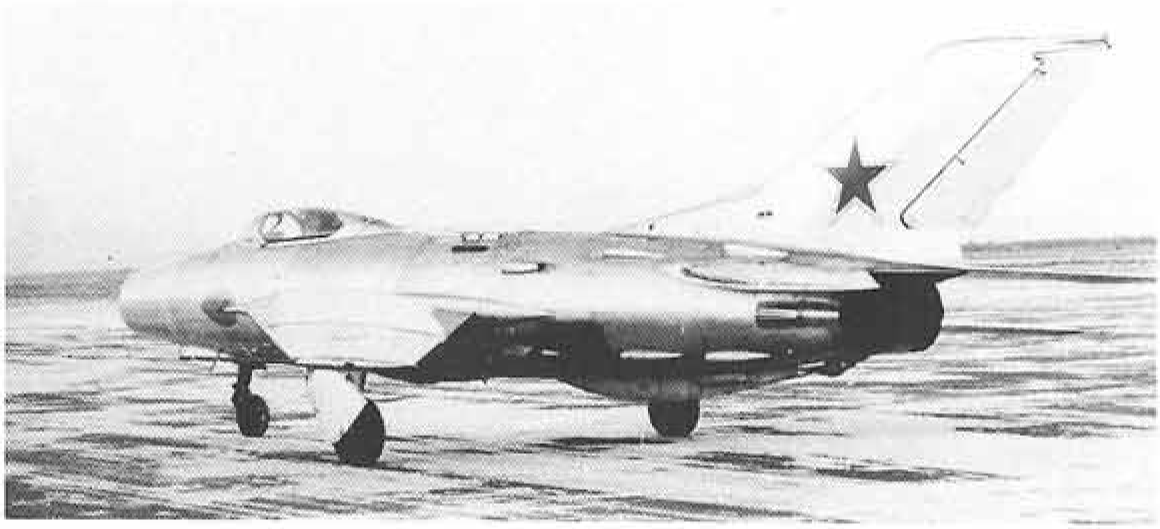
All four SM-12 aircraft were fitted with an improved flight-control system. The irreversible power units were the BU-13MSK for the tailplanes, causing a blister fairing at the kink on the fin leading edge, and the BU-13MK for the ailerons. The tailplane trim actuator was changed to the APS-4MD, with four times the speed of output. To make up for loss of one gun, provision was made for inboard pylons ahead of the wing, in line with those on the MiG-19S behind the main landing gear, with attachments for ORO-57 rocket launchers.

Generally similar, the SM-12/2, SM-12/3 and SM-12/4 were each powered by R3-26 engines. These again had a multishock inlet with translating conical centrebody, extra engine-cooling inlets and new afterburner heat shields with no rear 'pen-nib' fairing round the nozzles. The air-data boom was mounted on a bracket immediately in front of the nosewheel bay, and SM-12/3 and -12/4 had no wingtip booms. SM-12/3, which had a grossly enlarged steel panel adjacent to the guns, was photographed with two ORO-57 launchers and two tanks, and also with four ORO-57.

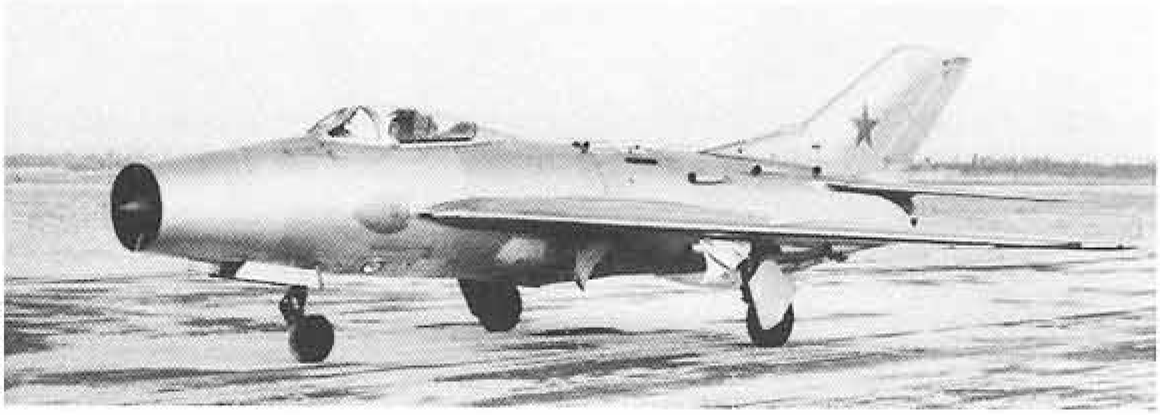
Few details of any SM-12 aircraft have been found, other than that SM-12/3 had a loaded weight of 7,695kg (16,964lb), and reached the startling maximum speed of 1,930 km/h (1,199mph, Mach 1.817) and a service ceiling of 18,000m (59,055ft).

SM-12PM

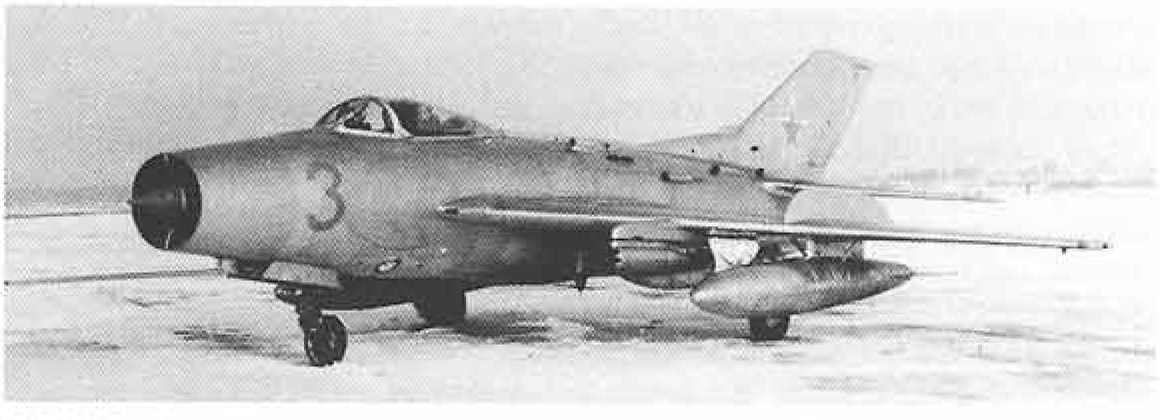
This fifth aircraft was fitted with RP-21 (SD-30, also rendered as TsD-30) radar, with the dish antenna inside a greatly enlarged nosecone. This in turn demanded a larger surrounding inlet duct, so the forward fuselage had only slight taper. The engines were two R3-26 with installation features as



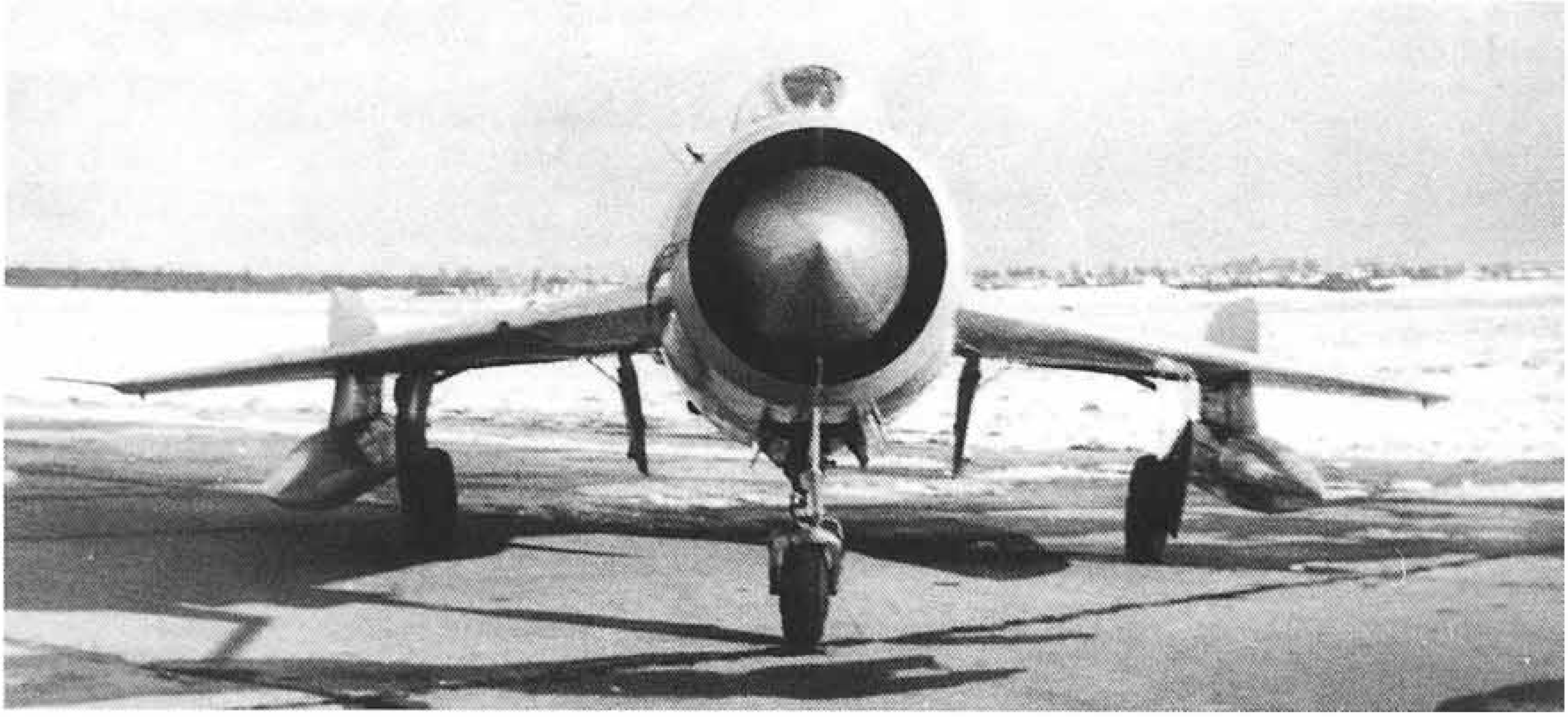
SM-12/1 (no pitot). (OKB)



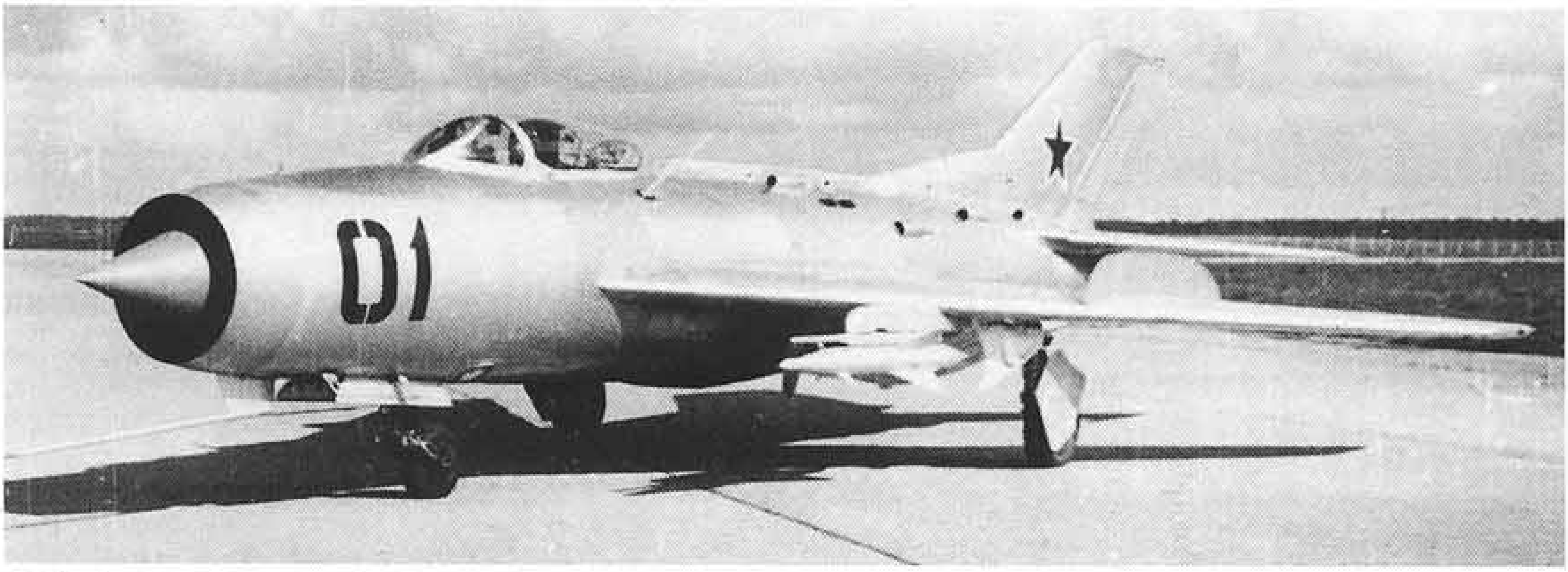
SM-12/2. (OKB)



SM-12/3 with two UB-57 and two tanks. (OKB)



SM-12PM with supersonic tanks. (Yefim Gordon archive)



SM-12PM with RS-2U missiles. (OKB, RART/GP)

in SM-12/2 and SM-12/3. The new radar (none was fitted in previous SM-12 aircraft) enabled a guidance beam to be provided for two K-5M missiles, carried on APU-4 rails on pylons which in earlier SM-12 aircraft had supported ORO-57 pods. Two more could be carried on the outer pylons in lieu of tanks. This missile was coming into production as the RS-2U, for use on the MiG-19PM. All guns were removed, and the tailplane power unit was the original BU-14MS, with no dorsal-fin blister. Other features included a long air-data boom mounted on a larger under-nose pylon at negative incidence, a uhf/vhf radio installation with blade antenna sloping on the left of the canopy instead of on the right, and a new rail-type telemetry antenna beside the left nosewheel door. In one photograph aircraft 'Red 01' is carrying no missiles but two tanks of a new design cleared for carriage at the maximum speed of the aircraft, mounted on large fence-type pylons.

Factory testing began in late 1957, and the SM-12PM reached 1,720km/h (1,069mph, Mach 1.62). The time of 4 minutes to climb to 10,000m (32,808ft) is reasonable, and suggests that a reported figure for the SM-12 of 3.2 minutes to the extreme of 18,000m (59,055ft) must be mistaken.

SM-12PMU

This final member of the SM-12 family was intended to reach altitude faster than any other interceptor. As well as two R3M-26 main engines the underside of the fuselage was occupied by a U-19D rocket package. Underwing pylons were provided for two or four RS-2U missiles. This aircraft also served as the testbed for the RV-U precision radar altimeter, the SOD air-traffic selective-identification transponder and the SRO-2 IFF (later called 'Odd Rods' by the ASCC), with three rod antennas projecting above the fin.

SM-2A

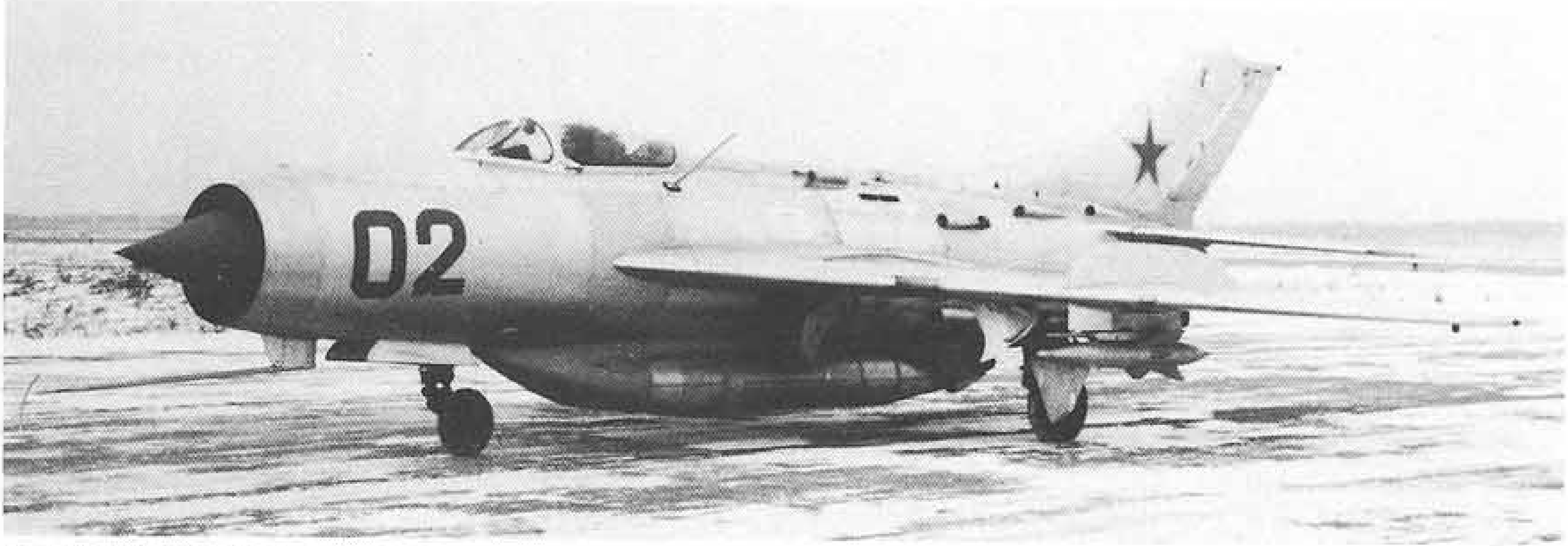
This testbed was a MiG-19 fitted with two/four ARS-70 heavy rocket launchers.

SM-2B

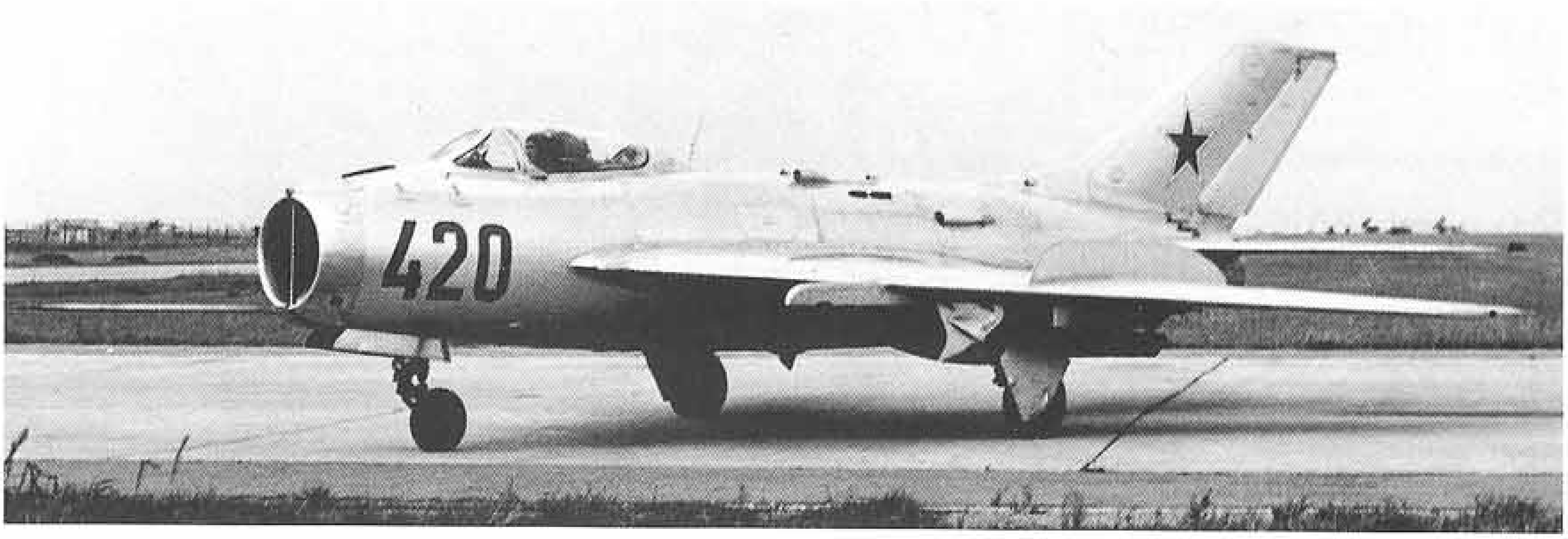
This testbed was a MiG-19 fitted with two TRS-190 rockets.

SM-2I, SM-6

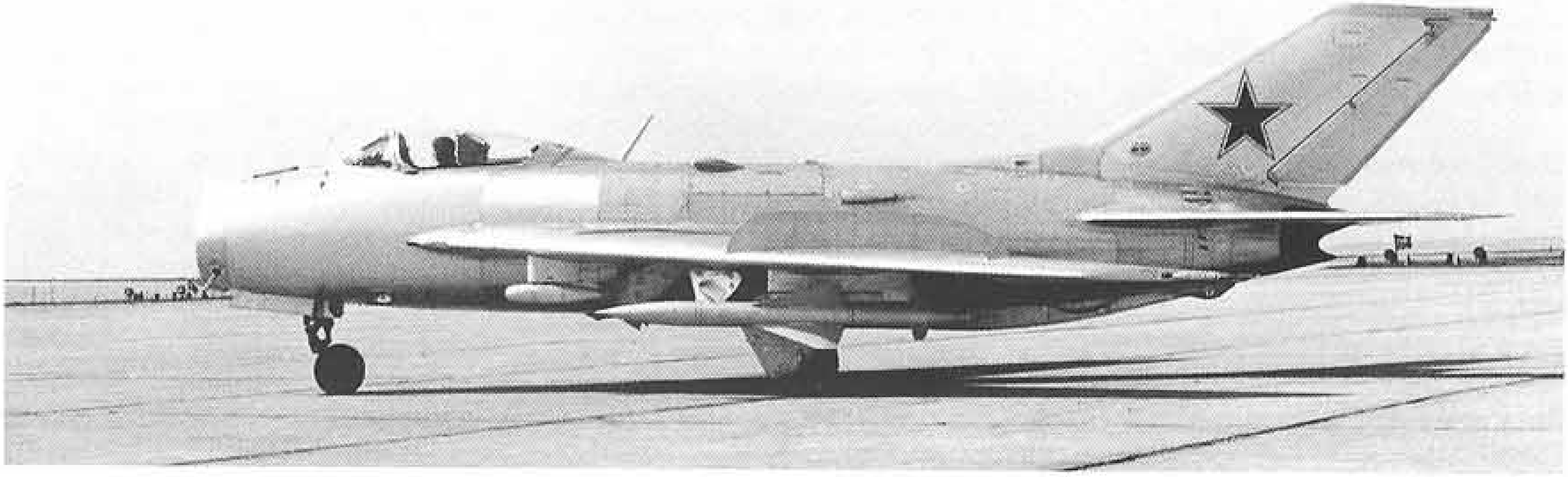
These two testbeds were early MiG-19s which in 1959 served as carrying aircraft for trials with the K-6 semi-



SM-12PMU with RS-2US missiles. (OKB)



MiG-19, SM-2A, with four pylons for large rockets. (OKB)



MiG-19, SM-6, with K-6 missiles. (OKB)

active homing air-to-air missile. These were launched from short APU-26 interface shoes on the outboard universal pylons, while a target illuminator was installed on a pylon under the inboard leading edge.

SM-2V

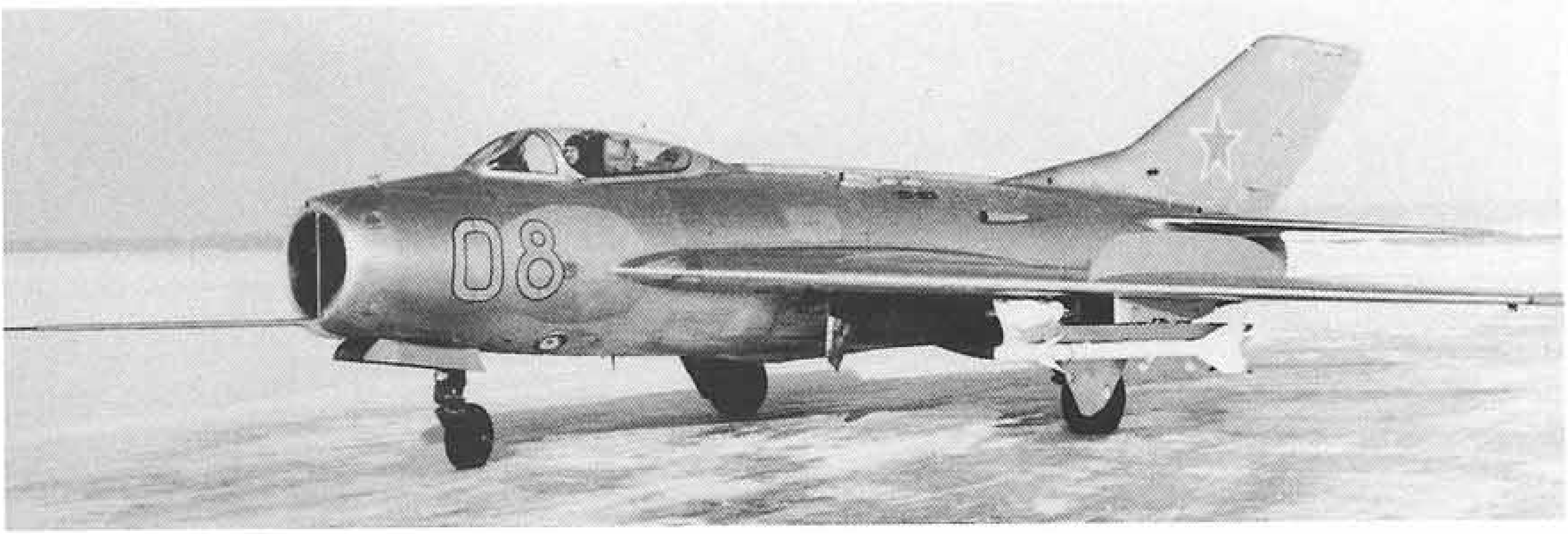
This testbed was a MiG-19 fitted with two ARS-212 rockets.

SM-9/3T

This MiG-19S callsign '08' was the most important trials aircraft used to develop the Soviet copy of the US Sidewinder AAM, the K-13. This simple IR-homing weapon was carried on the outboard pylon on an APU-13 launch rail. It began testing piloted by A V Fedotov on 11 February 1959, P M Ostapenko completing the task on 3 March. Missiles were carried at Mach 1.245 without affecting handling. The K-13 then went into production as the R-3S, initially for the MiG-21F-13.

MiG-19M

With this designation the S M Alekseyev OKB converted 'tired' MiG-19S fighters into target drones. Most



SM-9/3T. (RART/GP)

flew with radio control, rather than a preprogrammed autopilot.

Foreign MiG-19s

Soviet-built MiG-19s were supplied to the following customer air forces: Afghanistan, MiG-19S; Albania, MiG-19PM; Algeria, MiG-19S; Bulgaria, MiG-19S; Congo, MiG-19S; Cuba, MiG-19, MiG-19S and MiG-19PM; Egypt, MiG-19S; the German Democratic Republic, MiG-19S and MiG-19PM; Hungary, MiG-19P; Indonesia, MiG-19S; Iraq, MiG-19S; Poland, *see* below; Romania, MiG-19S; Syria, MiG-19S; Vietnam, MiG-19S, MiG-19SF and MiG-19SV.

Czechoslovakia

The MiG-19S was produced under licence by the Aero Vodochody factory between 1958 and 1961. The number built was 103, with the designation S-105. Engines were imported.

Poland

The Polish Air Force operated the MiG-19P and MiG-19PM. Some articles cite the Polish designations 'Lim-7, Lim-7M, Lim-7P'. These are fiction.

China

In 1956 the People's Republic signed a licence with the Soviet Government to manufacture the MiG-19S and MiG-19P. Manufacture was assigned to the large and growing factory at Mukden, Manchuria, which was then being renamed Shenyang, in Liaoning. This was already producing the MiG-17. The MiG OKB gave the fullest support, and the first nineteen MiG-19P aircraft were assembled from Soviet parts. The RD-9BF-811 engines were imported, but were soon to be made under licence by the Shenyang Engine Factory (later called Liming Engine Manufacturing Corporation) as the WP6. The first engine tested, in 1958, was a failure, but with better quality control production of engines was started in 1961.

The first Chinese-assembled MiG-19P was tested by Vang Yukhai on 17 December 1958. A year later (date not available) test pilot Yu Keming began flight development of the J-6, the Chinese-built MiG-19S. However, the 'Great Leap Forward' halted production, the teams were dispersed for re-education, and when they reassembled in 1963 only fifteen of the three hundred workers returned. Gradually production built up, and in 1967 testing began of the JZ-6 reconnaissance version. In the same year production started of the J-6A interceptor armed with two FL-2 (Sidewinder copy) missiles.

More important was the JJ-6 dual trainer, developed entirely at Shenyang to meet a 1966 requirement. The hinged/sliding canopies have a straight top, and most have one gun. The prototype flew in November 1970, and 637 were built, ending in 1986. In 1969 testing began of the J-6-III, powered by uprated WP-6A engines fed by an improved inlet with a fixed central cone. By this time the Shenyang factory was beginning design of the Q-5 fighter/bomber, derived from the MiG-19, with side inlets.

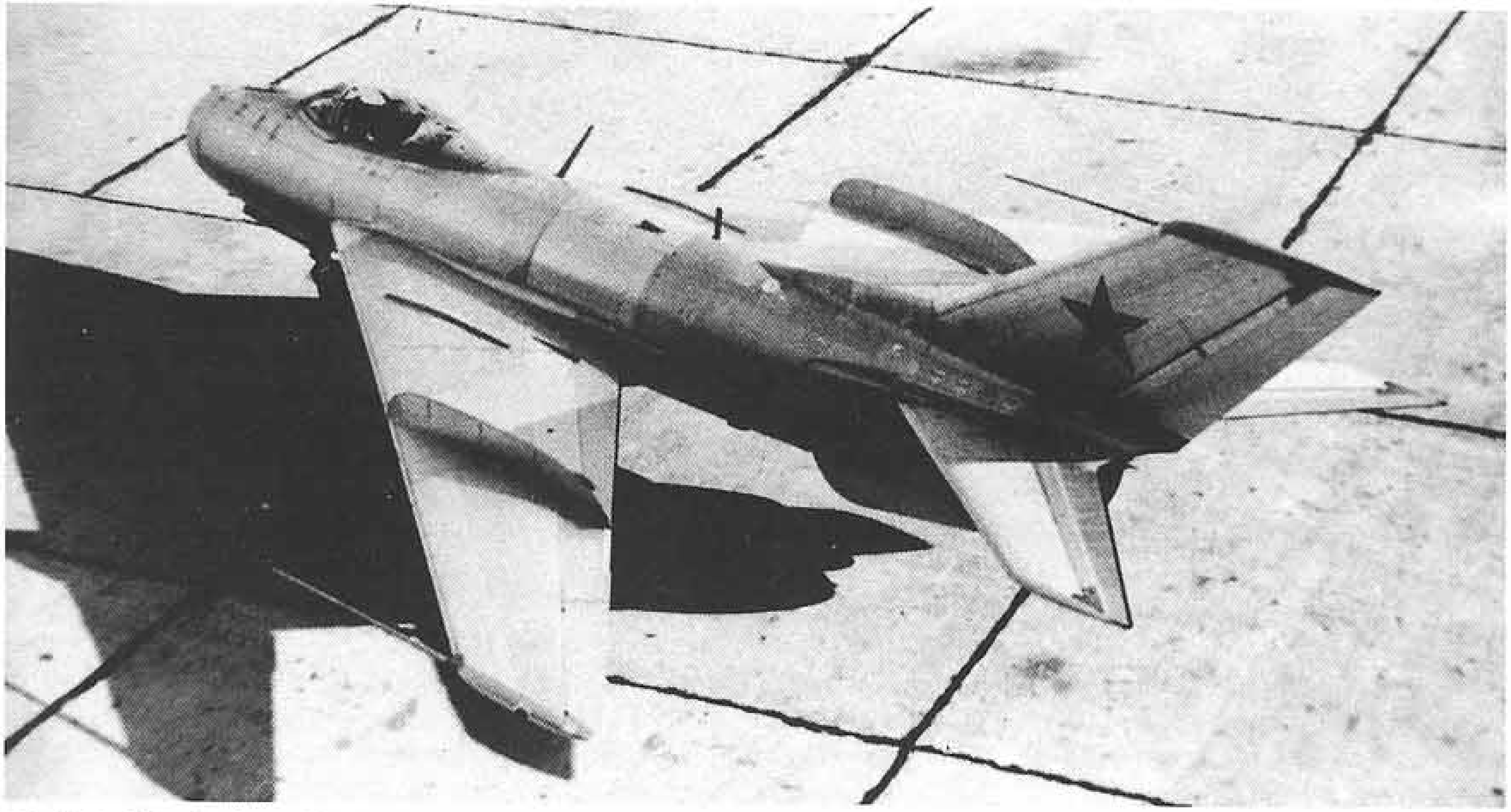
Excluding exports (called F-6) and Q-5 versions, the Shenyang factory manufactured at least 2,500 J-6 aircraft. Export customers included Albania, Bangladesh, Cambodia, Egypt, Iran, Iraq, North Korea, Somalia, Sudan, Tanzania, Uganda and Zambia.

Experimental interceptors

Throughout the 1950s the Soviet Union was assumed to be under threat from Western nuclear bombers, and its airspace was repeatedly violated by high-altitude reconnaissance aircraft. The MiG OKB strove unceasingly to develop interceptors with sufficient performance and reliability to offer a defence. This work was done in parallel with the development of the MiG-19 – which, as already noted, was quickly and probably mistakenly downgraded in importance – and also of the light prototypes which led to the MiG-21. For convenience here all the experimental interceptors will be described as a single group, which began at 1,400km/h (870 mph) and finished at over 3,000km/h (1,865 mph).

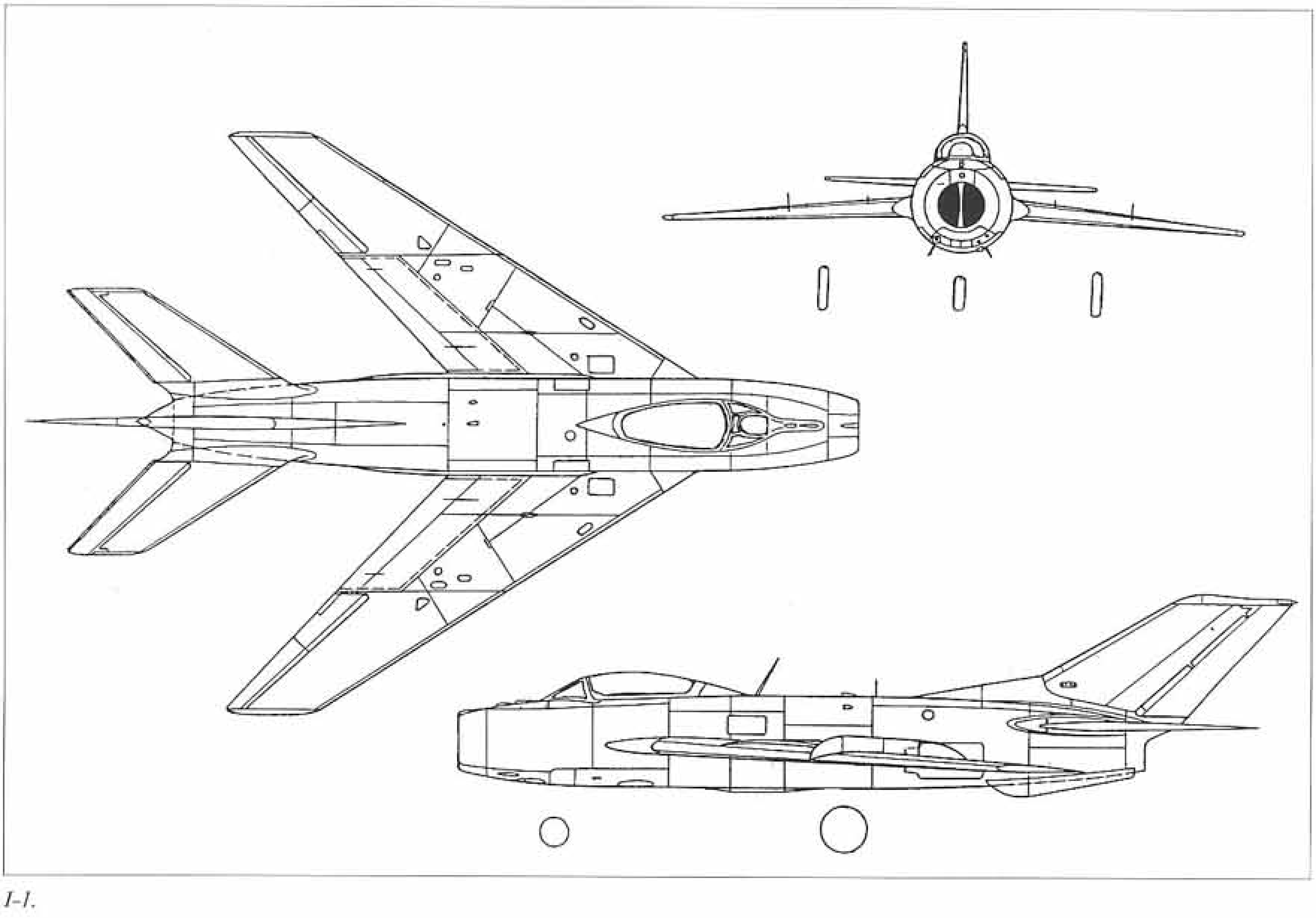
I-1, I-370

Around the time of Stalin's death in early 1953 the Council of Ministers were issuing orders for new interceptors at a rapid rate. The I-1, designated I-370 by the OKB, was authorized in May 1953, and the decree for the I-3, or I-380, followed two weeks later. Both were intended to safeguard against failure of the twin-engined fighters by matching similar aerodynamics with single large engines.

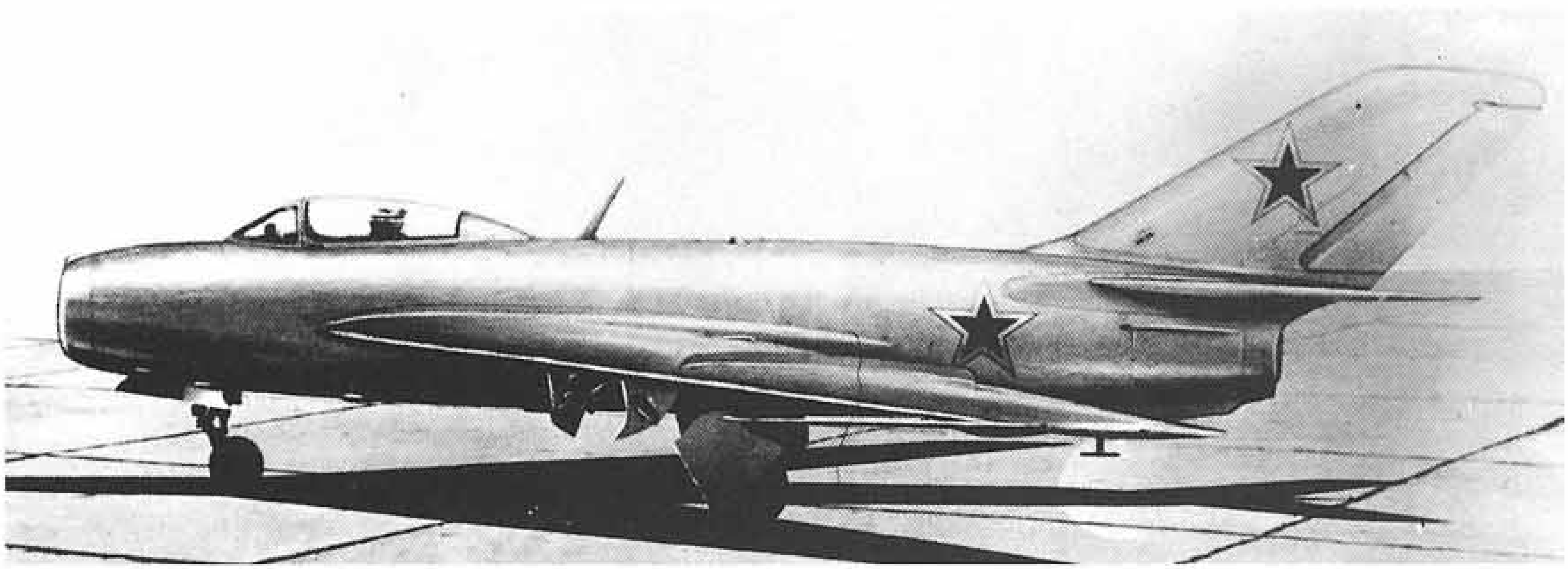


I-1, I-370. (Yefim Gordon archive)

The engine of the I-370 was the Klimov VK-7, which was essentially a scaled-up VK-1 (Nene). Maximum dry and afterburning ratings were 3,525kg and 5,235kg (7,771lb and 11,541lb), considerably less than that available to a MiG-19. This engine just fitted into the maximum diameter of the fuselage, which in almost all MiG aircraft at this time was 1.5m (59in). Most of the fuselage was of SM-9 type, except for the single engine installation and for addition of one frame at the front, which increased wheelbase to 4.508m (14ft 9½in). The inlet, drawn by the OKB as of reduced diameter, was in fact the same as the SM-9 prototypes. The tail



I-1.



Artist's impression of I-2. (Yefim Gordon archive)

was at first drawn with the tailplane at the top of the fin, but this too was modified and resembled an SM-9/2 with the tailplane of 4.1m (13ft 5⅜in) span positioned at the top of the fuselage. It differed in that the tailplane was mounted outboard of a fixed root and pivoted so that its incidence could be varied, as in the SM-9/1, the separate elevators pivoting on links to increase camber.

Other features included two large inclined ventral fins under the rear fuselage, rectangular 0.6sq m (6.5sq ft) airbrakes on each side of the fuselage immediately behind the wing, a frameless canopy, large fences, stiffeners above the inner wing and pitot tubes on the wingtips. There was a dorsal fin but no dorsal spine. The large plenum chamber reduced fuselage tankage to 2,025 litres (444.5gal), but there was provision for underwing drop tanks. Armament was as in the MiG-17, comprising one N-37D and two NR-23s all in the fuselage. The sight was the ASP-4N, with *Radal*-M radar rangefinder. An S-13 camera was mounted at the top of the nose, and an RV-2 antenna was under the port wingtip.

The I-370 was first flown by NII-VVS pilot Fyodor I Burtsev on 16 February 1955. Factory testing continued to 2 June, but the aircraft was not submitted to NII-VVS testing. Handling was generally similar to a MiG-19, and, despite the lower thrust, maximum speed was the same as for a MiG-19 at 1,452km/h (902mph) (in standard atmosphere the speed would have been 1,480km/h [918mph]). During its factory testing the engine was changed for a VK-7 cleared to a turbine entry temperature of 800°C, giving dry and afterburning thrusts of 4,200kg and 6,270kg (9,259lb and 13,823lb). This gave the improved performance listed below.

In 1956 the wings were removed and replaced by new wings with sweepback increased to 60° on the leading edge and 57° (instead of 55°) at the ¼-chord line. Fences and inboard stiffeners were removed. Span was unchanged, so area was slightly increased above the figure given below, which is the same as for a MiG-19. The rewinged aircraft was designated I-2. No performance figures are recorded, but the design speeds were not achieved. For many years an I-2 wing was used for instruction at the Moscow Aeronautical Institute.

Span 9m (29ft 6⅜in); length 12.7m (41ft 8in); fuselage length 10.44m (34ft 3in); wing area (approximate) 25sq m (269sq ft).

Weight empty 5,086kg (11,213lb); internal fuel 1,680kg (3,704lb); weight loaded 7,030kg (15,498lb); maximum with two tanks 8,300kg (18,298lb).

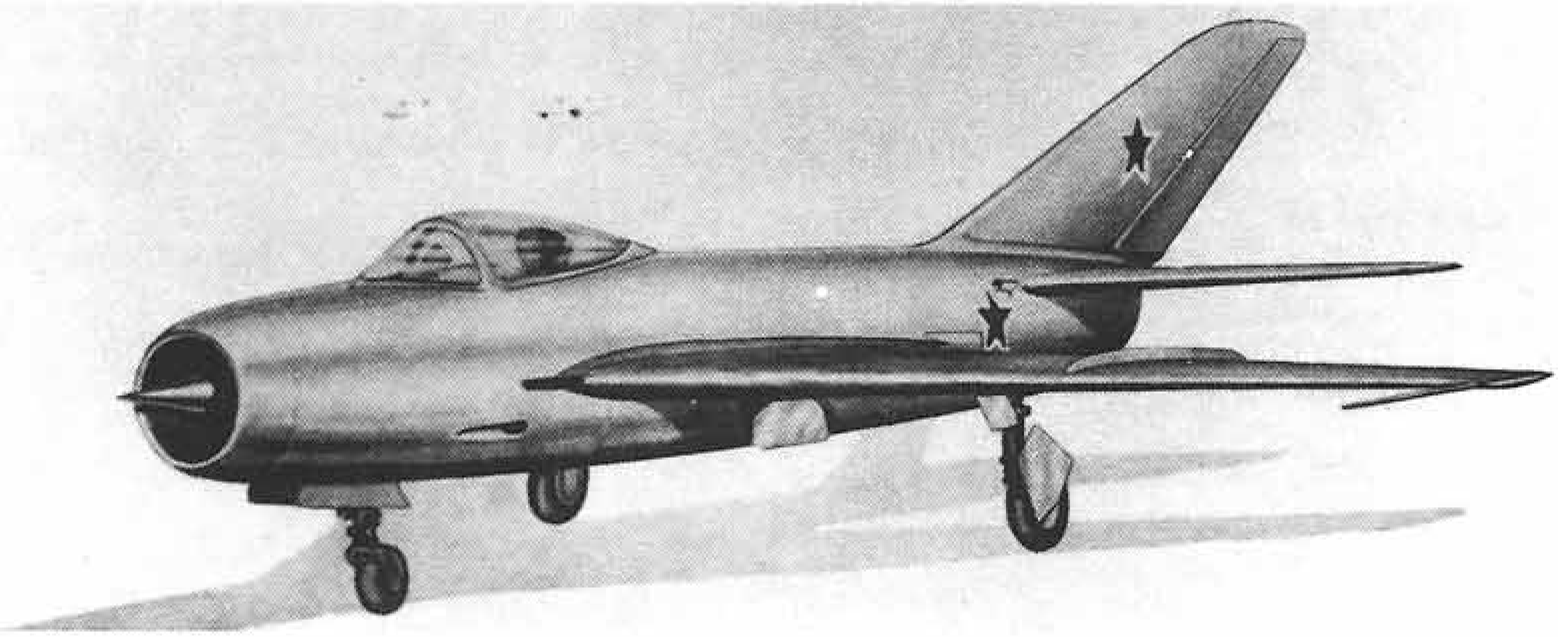
Maximum speed 1,520km/h (945mph, Mach 1.43) at 10,800m (35,432ft); climb to 5,000m (16,404ft) 1.15min, to 10,000m (32,808ft) 3min; service ceiling 17,000m (55,774ft); range (high altitude, two drop tanks) 2,500km (1,553 miles); takeoff run 464m (1,522ft); landing speed 180km/h (112 mph); landing run 730m (2,395ft).

I-3, I-380

On 3 June 1953 the Council of Ministers issued a directive ordering two new aircraft, the I-3 frontal fighter, called I-380 by the OKB, and the I-3P interceptor. These were to use a similar airframe, and the engine was to be the VK-3, one of the world's first bypass turbojets (low-ratio turbofan). Designed by S V Lyunevich in the Klimov bureau, this ran in 1952 and was qualified in 1954 at 5,730kg (12,632lb) dry and 8,440kg (18,607lb) with maximum afterburner. With such an engine, highly supersonic performance ought to have been realized immediately.

The wing was derived from those of the SM-9 and I-2, but sweep was increased yet again to 60° at the ¼-chord line, giving a leading-edge angle of 62°30′. For the first time there were three spars, and another new feature was that, to permit greater thickness at the root, the track-mounted slotted flaps had their inboard chord increased by a kink in the trailing edge. Each wing had a shallow full-chord fence at the flap/aileron junction. The two-part ailerons were driven by BU-13MK power units, the slab tailplanes mounted at mid-depth on the fuselage were driven by the BU-14MSK and had antiflutter weights projecting ahead of the tip, and the boosted rudder was mounted on a fin with sharper taper than previously and with the leading-edge root continued forwards into a ram air inlet for q-feel and engine-bay cooling. Unlike the twin-Mikulin engine installations, there were no other scoops for cooling air.

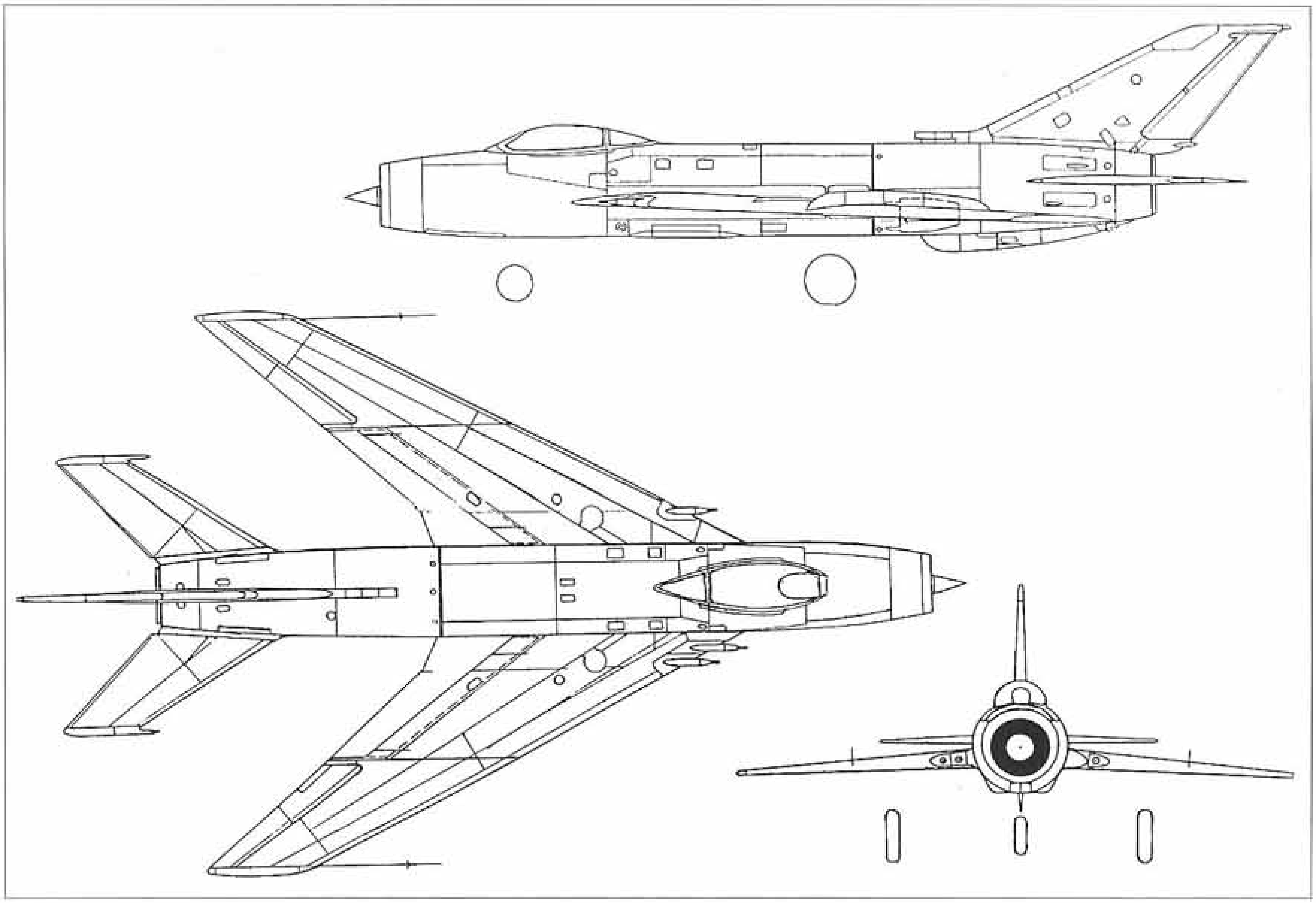
There were three airbrakes, one low on each side immediately behind the wing and the other in the underfuselage (without the bulge of the MiG-19). A long strake was mounted centrally under the rear fuselage, where there was a box housing a PT-2165-511 braking parachute of 15sq



Drawing from project documentation of I-3, with three guns. (Yefim Gordon archive)

m (161.5sq ft) area. The circular nose inlet contained a slim two-position central cone to improve supersonic pressure recovery. The landing gear was similar to those of preceding aircraft, but the canopy and armament were novel. The canopy comprised a small fixed transparent rear fairing and a single main section of blown Plexiglas in a peripheral frame of magnesium alloy, which at the front incorporated the multilayer bulletproof and optically flat windscreen. The entire unit pivoted up on hinges at the base of the windscreen, driven by a pneumatic ram. For emergency escape the canopy pivoted up on its hinges to serve as a protective windbreak ahead of the seated pilot before separating from the aircraft. Armament comprised three of the new NR-30 guns in the wing roots, one on the left and two on the right, with 65-round magazines between the front and centre spars. Design load factor of all I-3 aircraft was 8.

Development of the VK-3 engine proved difficult, causing serious delays to the I-3 programme. By 1955 both the I-3 and I-3P were being overtaken by later interception systems. The I-3 was therefore not completed in its original form but was modified during construction into the I-3U. The following weight and performance figures are estimates.



I-3.

Span 8.978m (29ft 5½in); length 14.83m (48ft 7⅞in); length from inlet to nozzle 12.275m (40ft 0⅛in); tailplane span 4.457m (14ft 7½in); track 4.036m (13ft 2⅞in); wheelbase 5.04m (16ft 6½in); wing area 30.05sq m (323.5sq ft).

Weight empty 5,485kg (12,092lb); internal fuel 1,800kg (3,968lb); weight loaded 7,600kg (16,755lb); maximum weight with two tanks 8,954kg (19,740lb).

Maximum speed 1,274km/h (792mph) at sea level, 1,311km/h (815mph) at 5,000m (16,404ft), 1,775km/h (1,103mph, Mach 1.67) at 10,000m (32,808ft); climb to 5,000m 0.81min, to 10,000m 1.9min; service ceiling 18,800m (61,680ft); range (internal fuel) 1,365km (848 miles); takeoff run 390m (1,280ft); landing run 726m (2,382ft).

I-3P, I-410 project

Though never completed, more details exist of this interceptor than of the I-3 day fighter. The airframes were '99 per cent similar', though the interceptor had more advanced systems and armament. The nose would have been 480mm (18.9in) longer, to house the *Uragan*-1 (hurricane) radar. The single wing fences were deeper, the slab tailplanes were driven by unidirectional BU-27/BU-28 power units, and all three airbrakes were of 0.6sq m (6.5sq ft) area each, the centreline brake being hinged to Frame 18 and extending to Frame 20. The main landing-gear units had KT-50 wheels with 800 × 200mm tyres, and the nose unit a KT-51 (540 × 140mm). The three internal tanks housed 2,300 litres (506gal), and there was provision for two 760lit (167gal) drop tanks.

The VK-3 engine was to drive an STG-12B generator to charge a 12SAM-28 battery. An AP-28M autopilot was fitted. Armament comprised two NR-30 guns, one in each wing root with 65 rounds (maximum 100), plus two rocket launchers. The latter were of the unusual ORO-57K type, each firing eight ARS-57 (mm) rockets. They were normally retracted into the wings and extended only for firing. The normal pylons could carry tanks, as noted, or FAB-250 bombs or single ARS-212 or TRS-190 rockets.

Like the I-3, the I-3P never received its engine, and may never have been built. The following weight and performance data are estimates.

Span 8.978m (29ft 5½in); length 15.6m (51ft 2⅛in); fuselage length 13.05m (42ft 9¾in); wing area (approximate) 30sq m (323sq ft); horizontal tail 8.17sq m (87.9sq ft); vertical tail 5.05sq m (54.4sq ft) including 1.24sq m (13.35sq ft) rudder.

Weight empty 6,276kg (13,836lb); fuel 1,900kg (4,189lb) internal, 3,160kg (6,966lb) with drop tanks; weight loaded 8,430kg (18,585lb); maximum (tanks and ARS-212) 9,947kg (21,929lb).

Maximum speed 1,700km/h (1,056mph, Mach 1.6) at 10,000m (32,808ft); rate of climb at 10,000m 2.04m/s (3,950ft/min); range at 12,000m (clean) 1,292km (803 miles), (tanks) 2,279km (1,416 miles).

I-3U, I-420

While under construction the I-3 was modified to incorporate most of the new features intended for the unbuilt I-3P, so that it finally emerged as the I-3U. In some documents this aircraft is designated I-5. The designation reflected the installation of the *Uragan*-1 radar. This was linked via a computer (designated OKB-857 after the design bureau responsible for the *Uragan* system) to an ASP-5M sight and also to the AP-36-118 autopilot so that, after *Gorizont* ground guidance astern of the target, interceptions could be made largely automatically. Against a bomber target the effective radar range was 17km (10.6 miles).

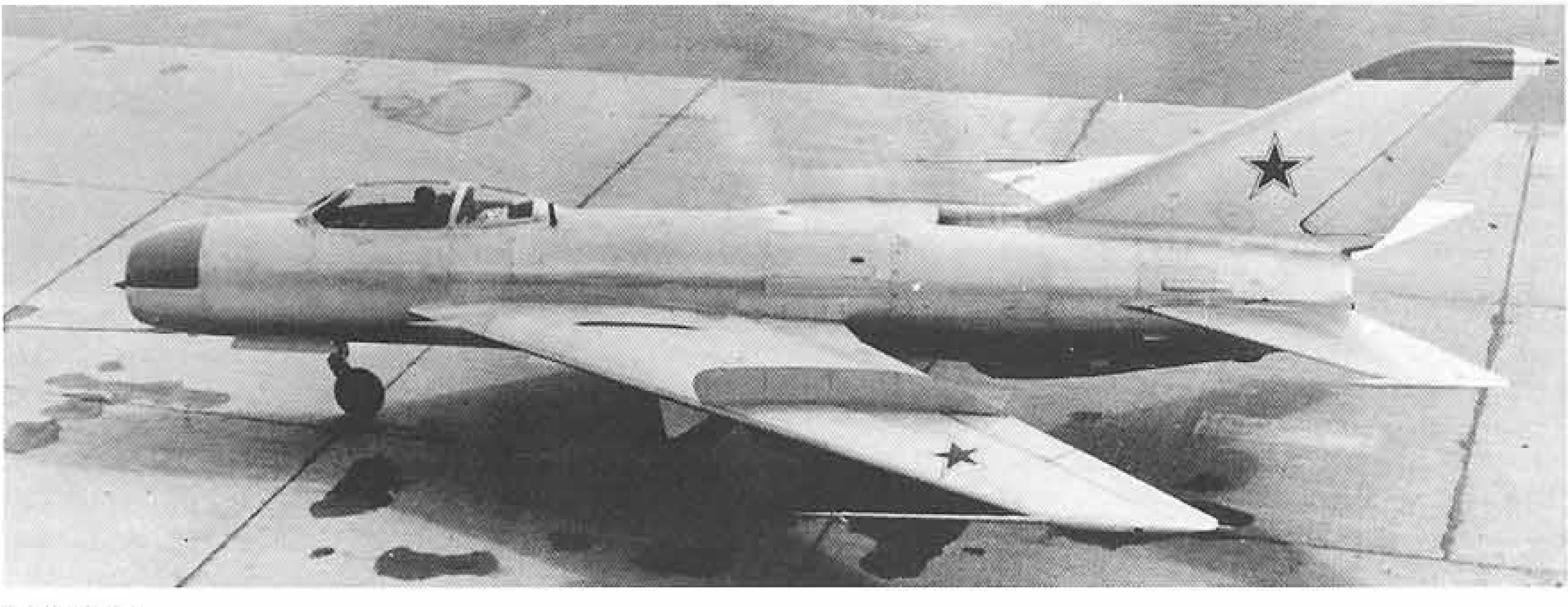
The airframe was hardly altered, though the forward fuselage was again slightly lengthened and the dish antenna of the tracking radar was placed in a conical radome noticeably below the centre of the inlet. Three air-data probes were fitted, that on the nose being one of the first PVD types fitted with pitch and yaw vanes. The engine bay incorporated titanium, and the three airbrakes were again of 0.6sq m (6.5sq ft) area each. Armament was as planned for the I-3P, though with the I-3U there is no mention of the ARS-57 launchers being retractable. Avionics included RSIU-4B radio with a small blade antenna on the left of the canopy, ARK-5 direction finder, MRP-48 marker receiver, RV-2 radar altimeter, *Sirena* RWR facing aft from the fin, and SRO *Khrom* IFF.

Altogether the I-3U was a fine-looking aircraft. Unfortunately, when it was at last completed and rolled out in 1956 the engine was still not available. Later in the year a flight-cleared VK-3 engine was at last installed, and the performance figures given below are measured, not estimates. By this time the OKB was working on later aircraft.

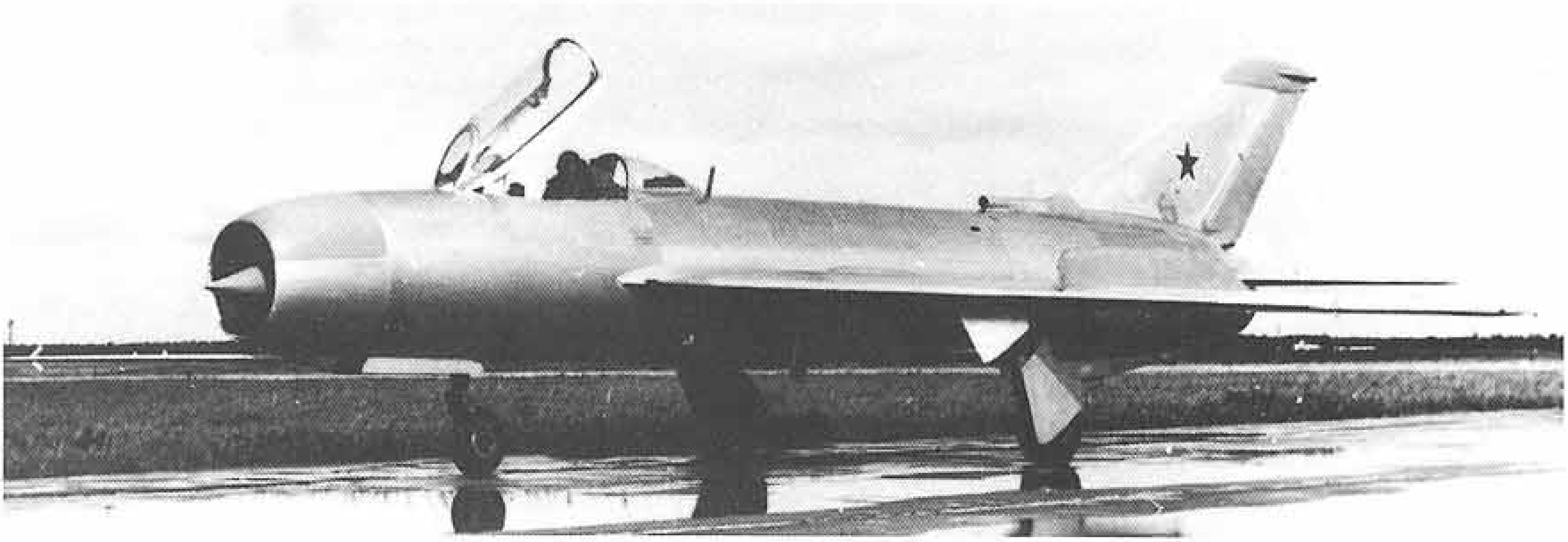
Span 8.978m (29ft 5½in) as before; length overall 17.86m (58ft 7⅛in), (excluding boom) 15.785m (51ft 9½in), (fuselage only) 13.54m (44ft 5in); track 4.036m as before; wheelbase 5.35m (17ft 6⅝in); wing area (approximate) 30sq m (323sq ft) as before.

Weight empty 6,447kg (14,213lb); internal fuel 1,800kg as before; loaded weight (clean) 8,500kg (18,739lb); (with two tanks) 10,028kg (22,108lb).

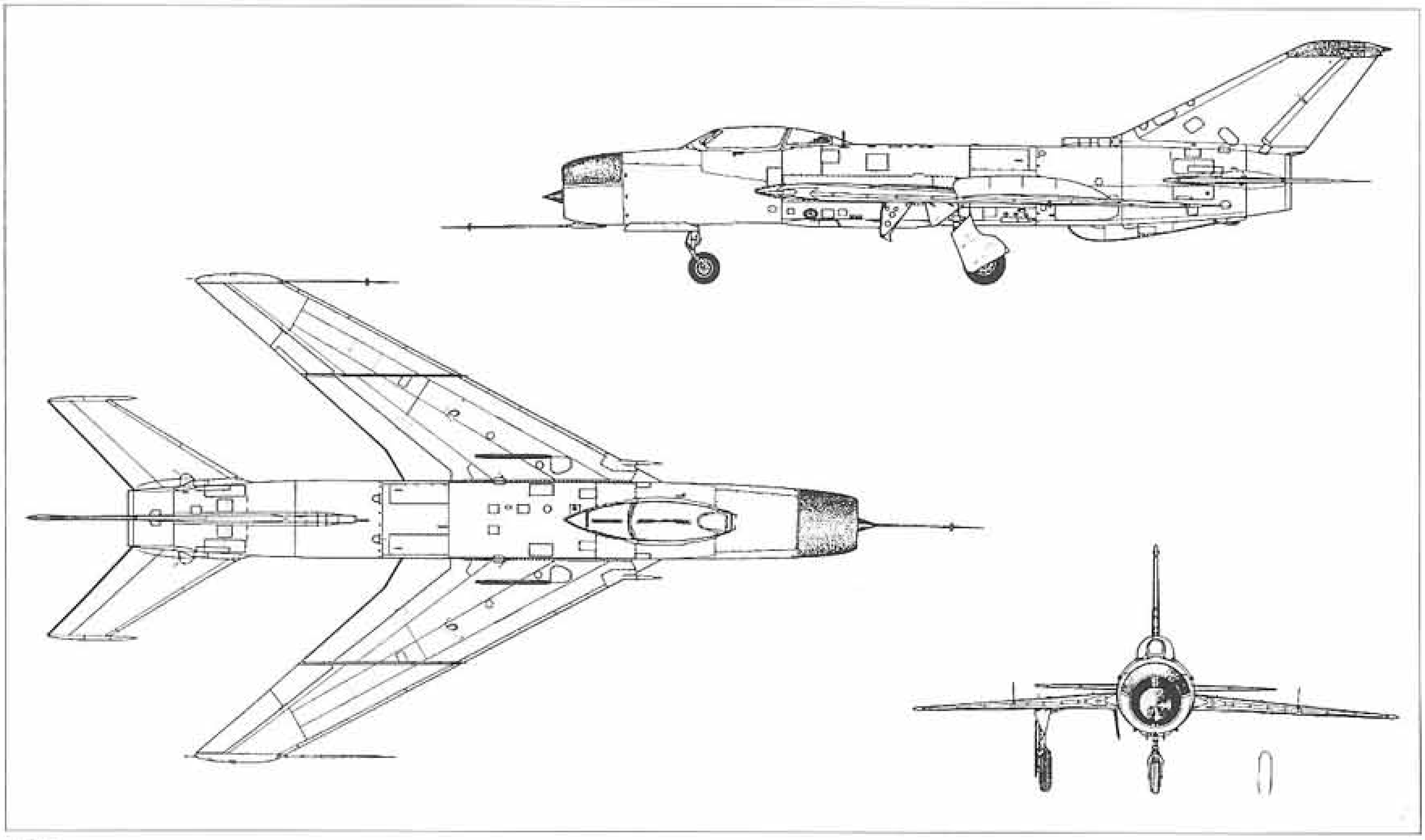
Performance at weight of 9,220kg (20,326lb), maximum speed 1,960km/h (1,218mph, Mach 1.845); climb to 15,000m (49,212ft) 2.4min; service ceiling 19,000m (62,336ft); estimated range (internal fuel) 1,290km (802 miles).



I-3U. (OKB)



I-3U. (OKB)



I-3U.

I-7U

No OKB designation is known for this experimental interceptor, which was authorized on 28 March 1956 in order to create an aircraft equipped with the OKB-857's *Uragan* radar and powered by an engine replacing the troubled VK-3. The engine chosen was the AL-7, which after years of unrewarding toil gave engine designer Arkhip M Lyul'ka his first big success. This potentially excellent axial-flow turbojet had an overall diameter of 1.25m (49.2in), and thus fitted well into the standard MiG fuselage of 1.5m (59in) diameter. As supplied to the OKB the AL-7F had a maximum dry thrust of 6,240kg (13,757lb) and afterburning thrust of 9,210kg (20,304lb).

The intention was to base this aircraft on the I-3U, though this proved to be an unrealized objective. For a start, the fuselage was lengthened and the wing sweep reduced to 55° along the ¼-chord line. The wing retained a fixed leading edge, anhedral of –4° and single fences (surprisingly, reduced in height) at the flap/aileron junction. Profile was S-12s, 6 per cent thick, near the fuselage, changing to SR-7s with a thickness/chord ratio of 7 per cent at the tip. It returned to the two-spar layout, with 25 ribs in each wing, but with thicker machined skin panels; this was the first MiG aircraft designed to a load factor of 9. Highly stressed parts used high-strength alloys including 30KhGSA, 30KhGSMA and V95, though most of the airframe remained D16.

The flaps were designed to extend to 15° for takeoff and 30° for landing. The kink in their trailing edges was accentuated to make the roots meet the fuselage at 90°. Like the smaller Ye (MiG-21) prototypes, each wing was not attached directly to the fuselage, at Frames 17, 19 and 21, but to a streamlined platform projecting ahead of and behind the wing root. The ailerons were completely new, with significant balance area ahead of the hinge and with structural ribs replaced by a low-density rigid core filling the interior.

The fuselage retained a circular section with a diameter of 1.5m (59in), maintained by 45 transverse frames. The cockpit extended between Frames 6 to 11. The guns in the wing roots occupied the sides from Frame 10 to 16. Equipment bays filled Frames 11 to 14A, and the bolted junction with the detachable rear fuselage was at Frames 28 and 29.

Like the ailerons, ribless foam-filled structure was used for the rudder, part of the slab tailplanes (which were reduced in span from 4.457m to 4.434m, 14ft 6⅝in) and for the airbrakes. The tail was attached at Frames 37, 40, 43 and 44. The fin profile was S-11s, with a leading-edge sweepback of 60°. The airbrakes were redesigned, there being two pairs hinged diagonally to the flanks of the fuselage, one pair under the leading edge of the wings extending between Frames 11 and 15, and the other under the trailing edge as before. All four were of 1.2sq m (12.9sq ft) area.

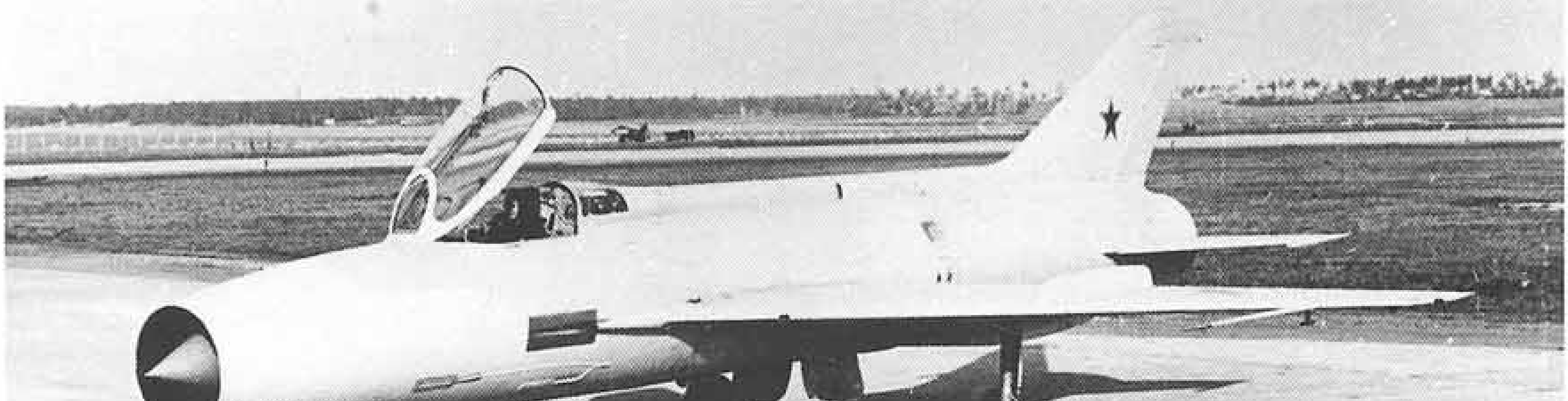
The main landing-gear units were also unlike those of the I-3U, but were identical in form to those of the Ye family, though stronger. Each main leg was pivoted to a trunnion between a short false spar and the front of the rear spar, retracting diagonally inwards with the wheel rotating on the end of the leg to be accommodated vertically in the side of the fuselage outboard of the engine air duct. The bay was closed by a rectangular door in the fuselage outboard of the engine air duct and hinged under the wing root. This enabled the larger KT-69 wheels, with 850 ¥ 220mm tyres, to be accommodated with no cutout in the highly stressed wing root other than for the leg. The nosewheel had a 600 ¥ 155mm tyre. Compared with the I-3U, the track was significantly reduced, to only 3.242m (10ft 75/8in), but wheelbase was increased to 5.965m (19ft 67/8in).

The short false spar was terminated by a strong rib at 90° to the front spar machined from a forging. From this rib (No. 8) inwards to No. 4, immediately in front of the main-leg bay, the wing was sealed to form a 300lit (66gal) integral tank. This increased internal fuel capacity to 2,530 litres (556.5 gal). Tail controls were run above the fuselage in a long spine, and under the rear fuselage was a shallow centreline spine and a box for a PT-7M braking parachute. The canopy was of I-3U type, very like that of the Ye prototypes.

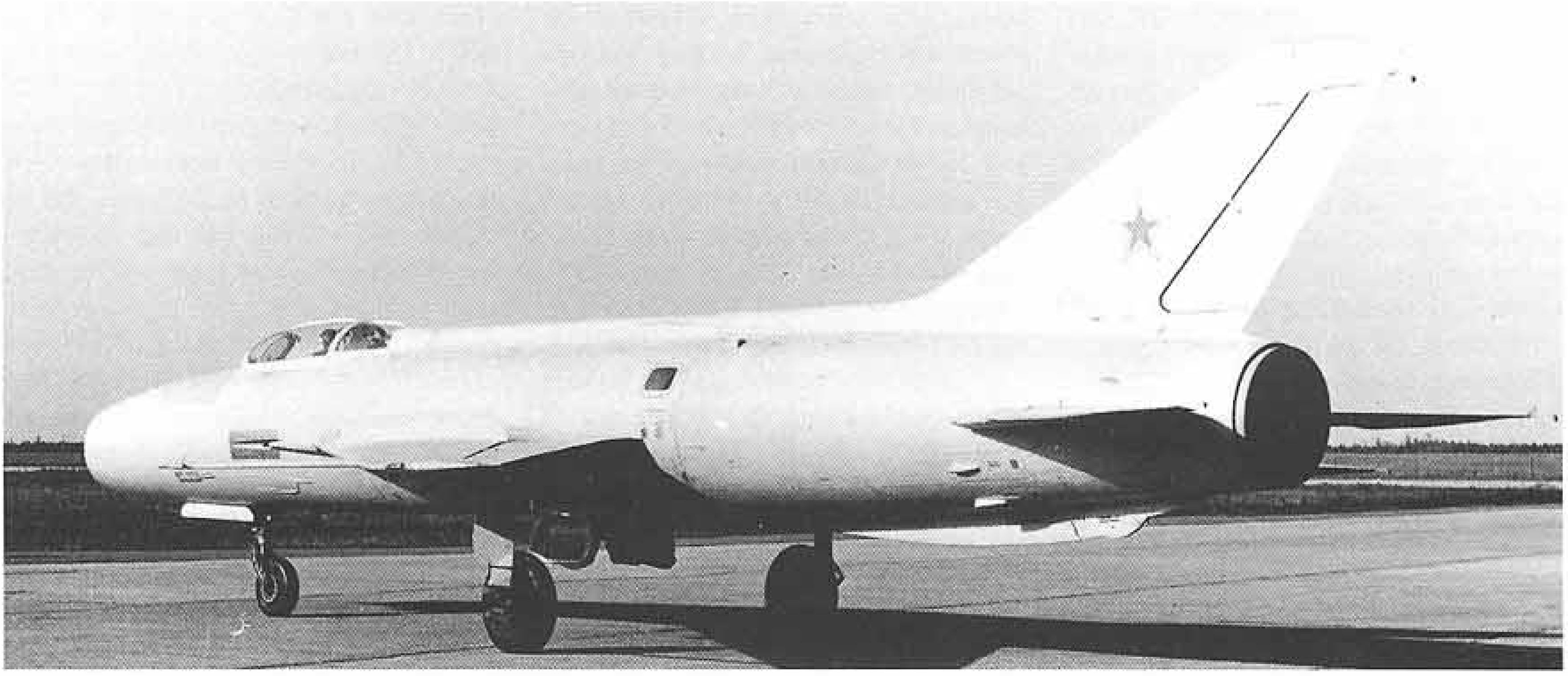
Armament remained two NR-30 guns, but they were moved right in to the wing roots. Their breeches were inside the wing-root attachment fairing, and their 65-round magazines (maximum, 100) were in the fuselage. Steel panels reinforced the fuselage beside each muzzle, with a channel to permit passage of the projectiles. In addition, sixty-four ARS-57 or ARS-57M rockets could be fired from four 'automatic launchers at the root of the wings'. Some authors have translated this to mean 'four normal pods on underwing pylons', but it seems clear that, again, the launchers were at the wing roots and were retractable, though illustrations have not been found.

The designation I-7U again referred to the installation of *Uragan-1* radar, with the dish scanner inside a nosecone in the inlet. This was not linked to the AP-36 autopilot. Other avionics included RSIU-4V radio (with no external antenna), ARK-5 radio compass (with antenna in the top of the canopy), RV-2 radar altimeter (with antenna under the port wingtip), OSP-48 landing system, MRP-48P marker and *Khrom-Nikel* IFF. A PVD air-data boom was mounted inboard of each wingtip, and the altimeter was an SGO-8. The engine drove a GS-12TP generator to charge two 15STsS-54A batteries.

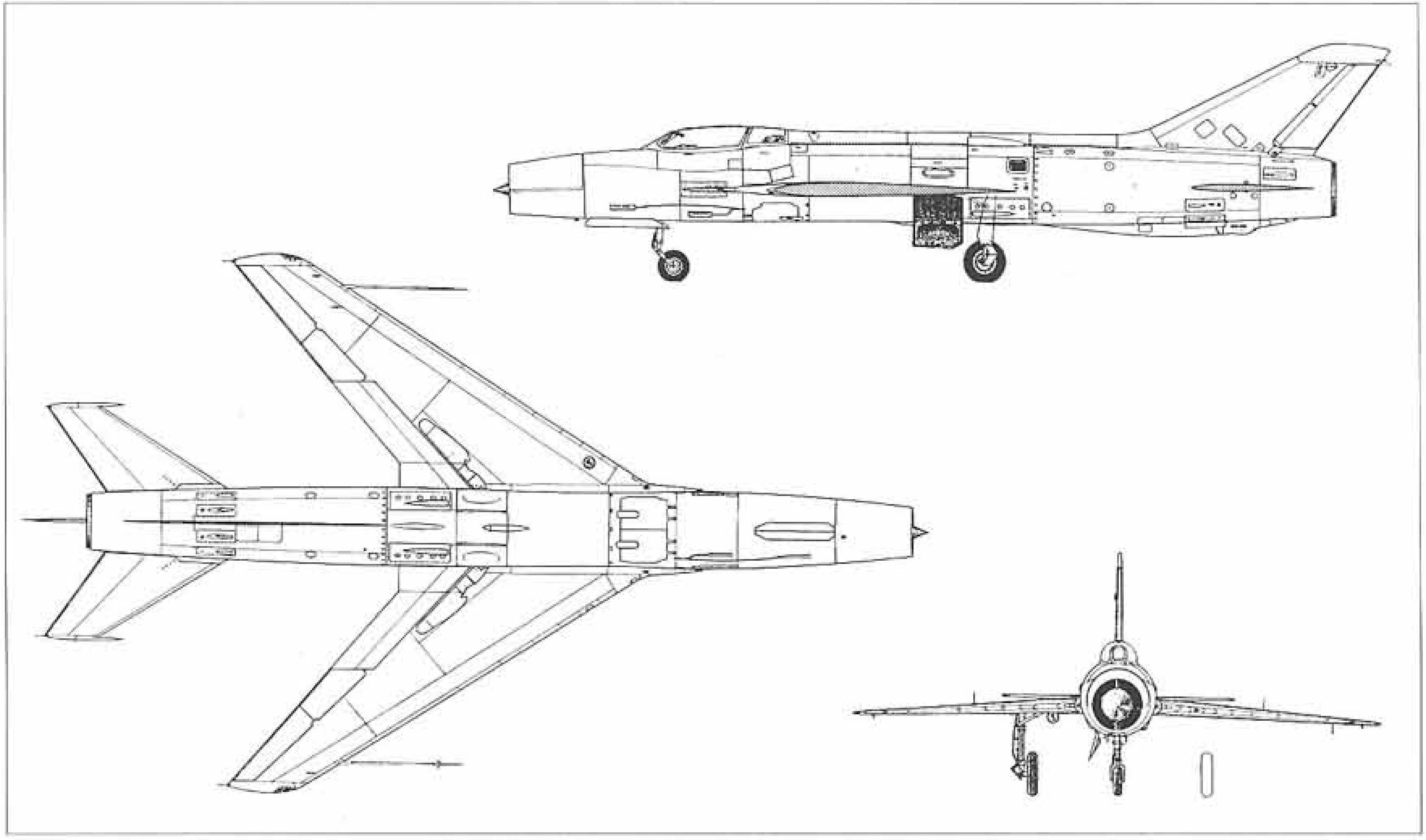
Rolled out and photographed unpainted, the I-7U was later painted in a light colour (almost certainly white) all over. Factory testing was conducted at the LII, the pilot being G K Mosolov. Taken by road to Zhukovskiy on 26 January 1957, it took until 17 April to get the I-7U airworthy and begin taxi tests. The first flight, on 22 April, was trouble-free, and in some respects – notably rate and angle of climb – the I-7U was outstanding. However, in twelve flights, problems with the instrumentation prevented any accurate measurements being taken of level speeds with afterburner. In some accounts it is incorrectly stated that the aircraft was incapable of getting within 880km/h of the design figure, but in fact the speeds in dry thrust were close to prediction. Speeds in afterburner should also have been close to the design values, though beyond about Mach 1.65 the aircraft tended to roll to the left.



I-7U. (OKB)



I-7U. (OKB)



I-7U.

On Flight 13, on 21 June, the right main landing-gear leg folded inwards on landing, damaging the wing. After repairs at OKB-155, but apparently still without accurate instrumentation, the I-7U made six more flights between 26 September and 24 January 1958. On 12 February it was returned to the OKB to be converted into the I-75.

Untypically, and due largely to the long reliance on Klimov's VK-3 engine, this was a time when the OKB slipped behind its immediate competitor. The design bureau of Sukhoi, restarted after Stalin's death, had flown an interceptor powered by the AL-7F on 8 September 1955. Their lead of over 18 months was mainly responsible for their designs being picked as the frontal fighter (Su-7 swept wing) and interceptor (Su-9 delta), in preference to the rival MiG aircraft.

Span 9.976m (32ft 9¼in); length 16.925m (55ft 6⅜in); length of fuselage (from inlet lip) 15.692m (51ft 5¾in); wing area 31.9sq m (343sq ft).

Weight empty 7,952kg (17,531lb); internal fuel 2,000kg (4,409lb); weight loaded 10,200kg (22,487lb); maximum weight loaded (drop tanks are not mentioned in OKB documents but are assumed here) 11,540kg (25,441lb).

Maximum speed (dry thrust at 11,000m) 1,420km/h (882mph, Mach 1.34); design thrust (maximum afterburner at 10,000m) 2,200km/h (1,367mph, Mach 2.07); service ceiling 19,100m (62,665ft); estimated range (internal fuel) 1,505km (935 miles); takeoff run 570m (1,870ft); landing speed 295km/h (183mph); landing run 900m (3,248ft).

I-7K project

This I-7 derivative was to have been fitted with a little-known radar, *Almaz*-3, providing a target illuminating beam for the armament of K-6 missiles. This semiactive homing missile was being developed by a group called OKB-2, and had been tested on the SM-6 (MiG-19). Four were to be carried, on a twin-rail APU-9 launcher under each wing, the guns being removed. In addition there were to be four retractable launchers each with tubes for four ARS-57 rockets. This aircraft was never built, and data below are design figures.

Dimensions as I-7U.

Weight loaded (normal) 9,800kg (21,605lb).

Maximum speed 1,940km/h (1,205mph, Mach 1.826) at 10,000m (32,808ft); climb to 10,000m 1.25min, or 2.5min in MIL thrust; service ceiling 18,500m (60,696ft), or 16,550m (54,300ft) in MIL thrust; range at 10,000m, 1,340km (833 miles), or 1,805km (1,122 miles) with tanks; takeoff run 630m (2,067ft); landing run 990m (3,248ft) or 670m (2,198ft) with parabrake.

I-75

On 7 March 1957 the OKB received a directive ordering the construction of two new interceptor prototypes derived from the I-7U. They comprised the I-75, powered by an AL-7F engine, and the I-75F, powered by an uprated AL-7F-1. The I-75 was produced by rebuilding the I-7U. Mikoyan assigned Nikolai Z Matyuk to manage the programme.

The key feature of the new aircraft was that they were to be equipped with the *Uragan*-5B radar fire-control, which in operation formed part of the *Uragan*-5 ground-to-air control system. Though again a development by OKB-857, *Uragan*-5B had little in common with earlier *Uragan* systems. Whereas earlier installations had separate search and tracking antennas, *Uragan*-5B had a single dish antenna serving all functions. Transmitter power was multiplied by four, and the parabolic reflector was considerably larger to match it to the wavelength and give better discrimination. The radar was pilot-selectable to SEARCH (effective range at least 30km, 18.6 miles), TRACK (locked on to the target, from 20km, 12.4 miles) and finally FIRE (illuminating the target for homing missiles).

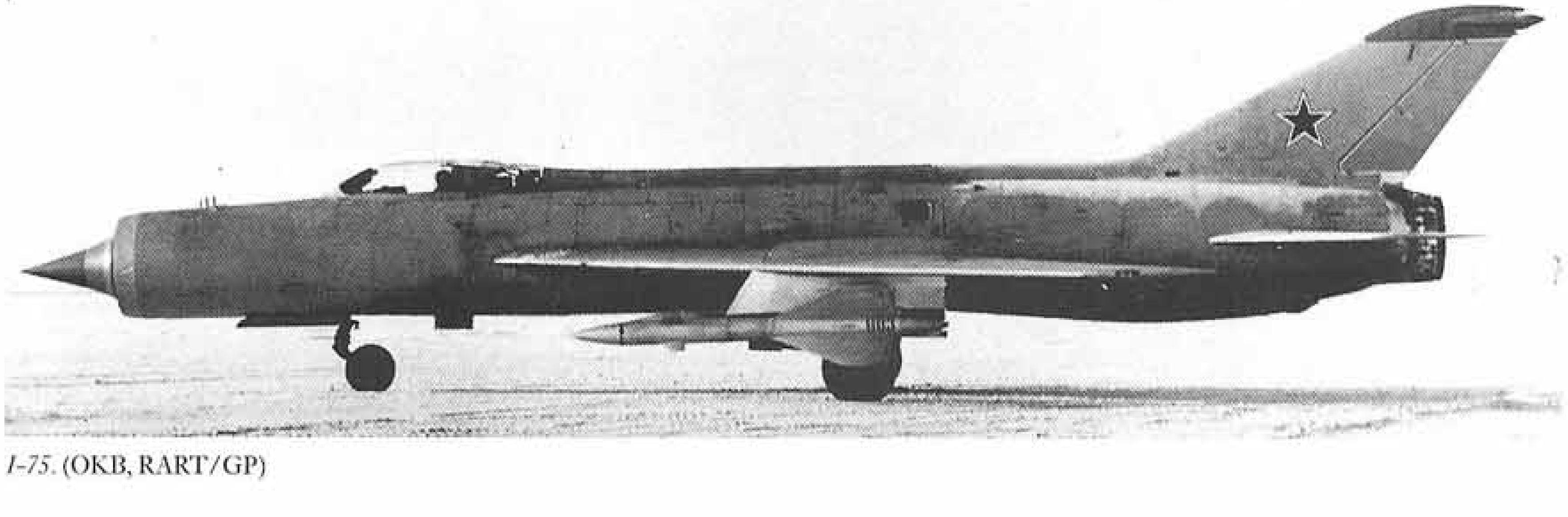
At this time several OKBs, including MiG, were busy developing guided missiles. For this interceptor the weapon chosen was the Bisnovat K-8, a large weapon with cruciform canard fins indexed in line with large aft-mounted wings with trailing-edge controls. Both aircraft carried one missile under each wing on a deep pylon almost in line with the overwing fence.

To convert the I-7U into the I-75 the entire forward fuselage was replaced by a new structure with the full 1.5m diameter of the fuselage maintained almost to the nose inlet. This enabled the previous small central nosecone to be replaced by a much larger cone able to accommodate the radar scanner and its drive mechanism. The exterior profile of the cone was of Oswatitsch type, in which at supersonic speed weak shockwaves are generated by three successive increases in cone angle, to slow the airflow with minimum loss in total pressure. This improved engine behaviour and thrust, especially at high altitude. The cone was fixed, but pressure recovery was further improved by providing for the inlet ring round the throat to translate (slide to front and rear). CIAM and CAHI assisted with the aerodynamics of the inlet.

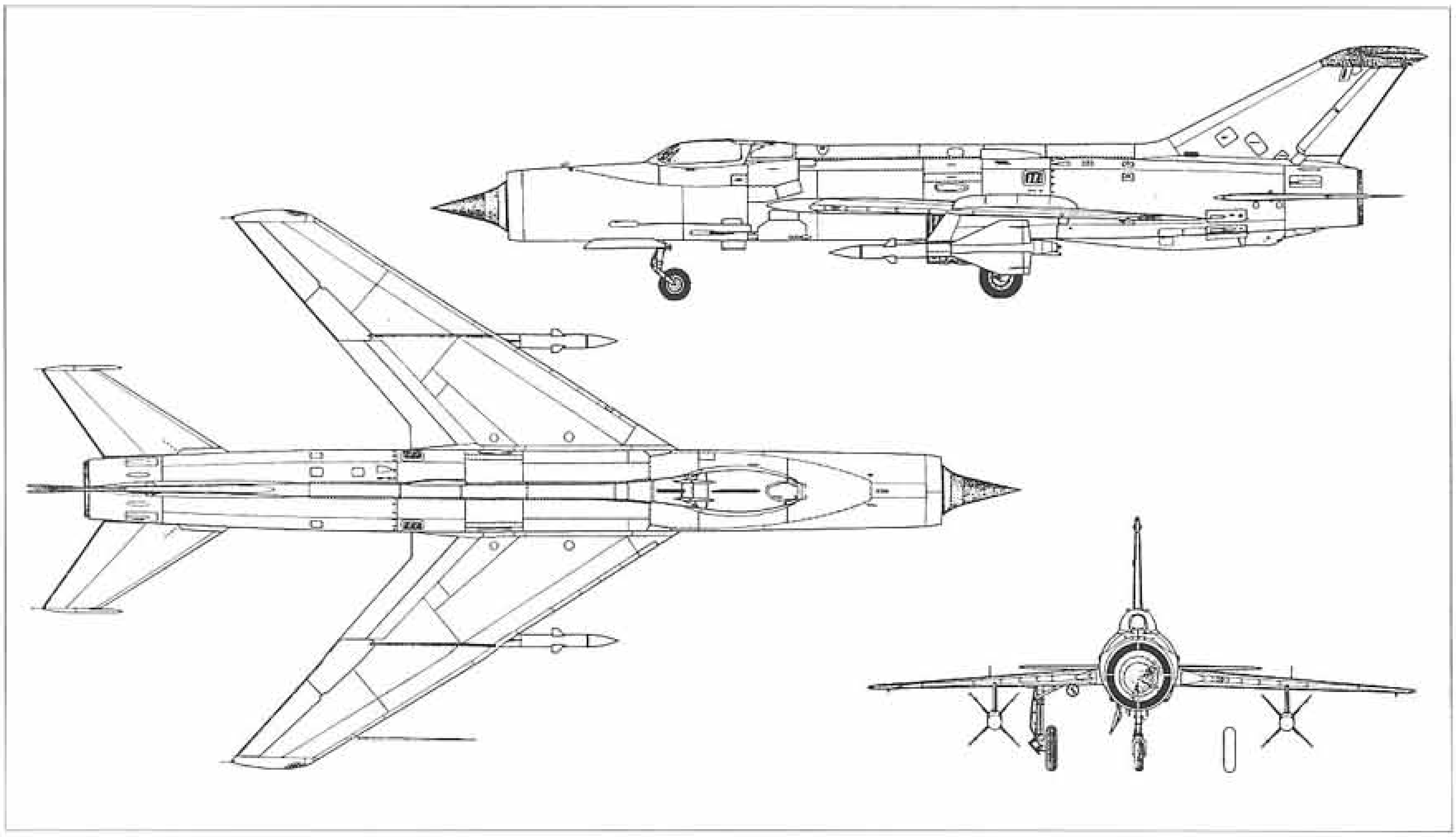
Geometrically similar to the I-7U, the landing gear again had KT-69 mainwheels, but with 880 × 230mm tyres, and a KT-78 nosewheel with a 600 × 155mm tyre, all fitted with disc brakes with antiskid control. The I-75 had slightly greater fuel capacity than the I-7U, partly because removal of the gun magazines made it possible to install five tanks in the fuselage. Together with two pairs of integral cells in the wings (two replacing the guns) the total was 2,610 litres (574gal). Provision was made for two drop tanks to be carried on inboard pylons, but it is possible these were never fitted.

Details of the I-7U flight-control system have not been published, so it is not known if the I-75 system was modified. The later aircraft had BU-44 power units to drive the ailerons, a BU-44B to drive the slab tailplanes and BU-45 to drive the rudder, with an ARU-3V q-feel system. The system was linked with the AP-39 autopilot, derived from the AP-36 fitted to the I-7U, via the *Uragan*-5D analog computer in order for the radar to steer the aircraft automatically on an interception course. The system was designed to intercept bombers travelling at up to 1,500km/h (932mph, Mach 1.41) at up to 20,000m (65,600ft).

There were several other modifications. The wings were fitted with new root sections without guns, attached directly to the fuselage instead of to a streamlined platform. The canopy was of MiG-21F type, physically linked to the seat during the start of the ejection sequence. The fin was modified with the leading edge swept at 61.5° instead of 64°, and its height was increased, partly because of the reduced sweep and partly by adding a new cap of dielectric material housing the RSIU-4V radio antenna and the aft-facing antenna of a *Sirena* RWR. Improved SRO-2 *Khrom-Nikel*



I-75. (OKB, RART/GP)



I-75.

IFF was fitted, with its rod antennas ahead of the windscreen. The PVD air-data boom on the port wing was removed. A second PT-7M braking parachute was added on the right of the ventral strake. Other equipment that differed from the I-7U included an ARK-541 radio compass, GS-18TP generator and two 15STs-45 batteries.

Without an operative *Uragan*-5B radar, the I-75 was taken to the LII field on 1 March 1958. It was unpainted, and in some photographs has a heat-stained rear fuselage. Problems with the canopy jettison system delayed the start of factory testing until 28 April. The pilot was again Mosolov, supported by I-75 chief engineer A N Soshin. The *Uragan*-5B was not installed until December 1958. The I-75 made thirty-four factory test flights.

Precise dates for the second aircraft are not known, but it was designated I-75F, reflecting the fact that its engine was the AL-7F-1, rated at 9,900kg (21,825lb) thrust with afterburner. The I-75F successfully passed State testing, but it had little chance of being selected for PVO service. Though technically inferior, the rival Su-9-51 system was already in production. Flight testing of both aircraft was discontinued on 11 May 1959. Despite the fact that these prototypes became known in the West, no ASCC name was allocated. The performance figures are those measured with the I-75, not the I-75F.

I-75. (OKB, RART)

Dimensions, as I-7U except length 18.275m (59ft 11½in); fuselage length 15.6m (51ft 2½in).

Weight empty 8,274kg (18,241lb); internal fuel 2,100kg (4,630lb); weight loaded (clean) 10,950kg (24,140lb); maximum (missiles and tanks) given as 11,470kg (25,287lb), a suspect figure because it is less than that confirmed for the I-7U.

Maximum speed (clean) 2,050km/h (1,274mph, Mach 1.93), (with missiles) 1,670km/h (1,038mph, Mach 1.57), (MIL thrust) 1,420km/h (882mph, Mach 1.336); design figures for climb to 6,000m (19.685ft) 0.93min, to 11,000m (36,089ft) 3.05min; service ceiling (Mach 1.6, afterburner) 19,100m (62,664ft), (MIL thrust) 18,550m (60,860ft); range (internal fuel) 1,470km (913 miles); take-off run 1,500m (4,921ft); landing speed 240km/h (149mph); landing run 2,080m (6,824ft) or (drag chute) 1,600m (5,249ft).

Ye-150

In 1955 the engine KB of A A Mikulin received an order to develop an afterburning turbojet specifically for the propulsion of air vehicles at Mach 3. The resulting R-15 engine was designed by S K Tumanskiy with a single axial-flow compressor with only five stages, giving the modest pressure ratio of 4.75, in the knowledge that at highly supersonic speeds far greater compression is achieved in the inlet system. The initial version, the R-15K, was to power the Tu-123 (K-15) *Yastreb* (hawk) surface-launched cruise missile. The engine weighed 2,590kg (5,710lb) and, thanks to its exceptional mass flow of 144kg (317.5lb)/sec, gave a thrust of 14,000kg (30,865lb) in full afterburner (it was designed to cruise in this regime).

This engine was obviously of interest for the propulsion of highly supersonic aircraft, and versions were eventually to power Mikoyan's Ye-152 family and later the twin-engined MiG-25. In late 1957 what had become the Tumanskiy bureau was ordered to develop the R-15-300 version (the designation reflected the factory number of the bureau) to power manned aircraft. This had a normal pilot-selectable control system and a different afterburner with an ejector nozzle, an extra profiled ring surrounding the variable primary nozzle which at supersonic Mach numbers induced extra air into the jet. Thrust ratings of the R-15-300 were 6,840kg (15,080lb) dry and 10,150kg (22,377lb) in maximum afterburner. At Mach 2.5 and above, the effective thrust was greatly augmented by the ejector nozzle.

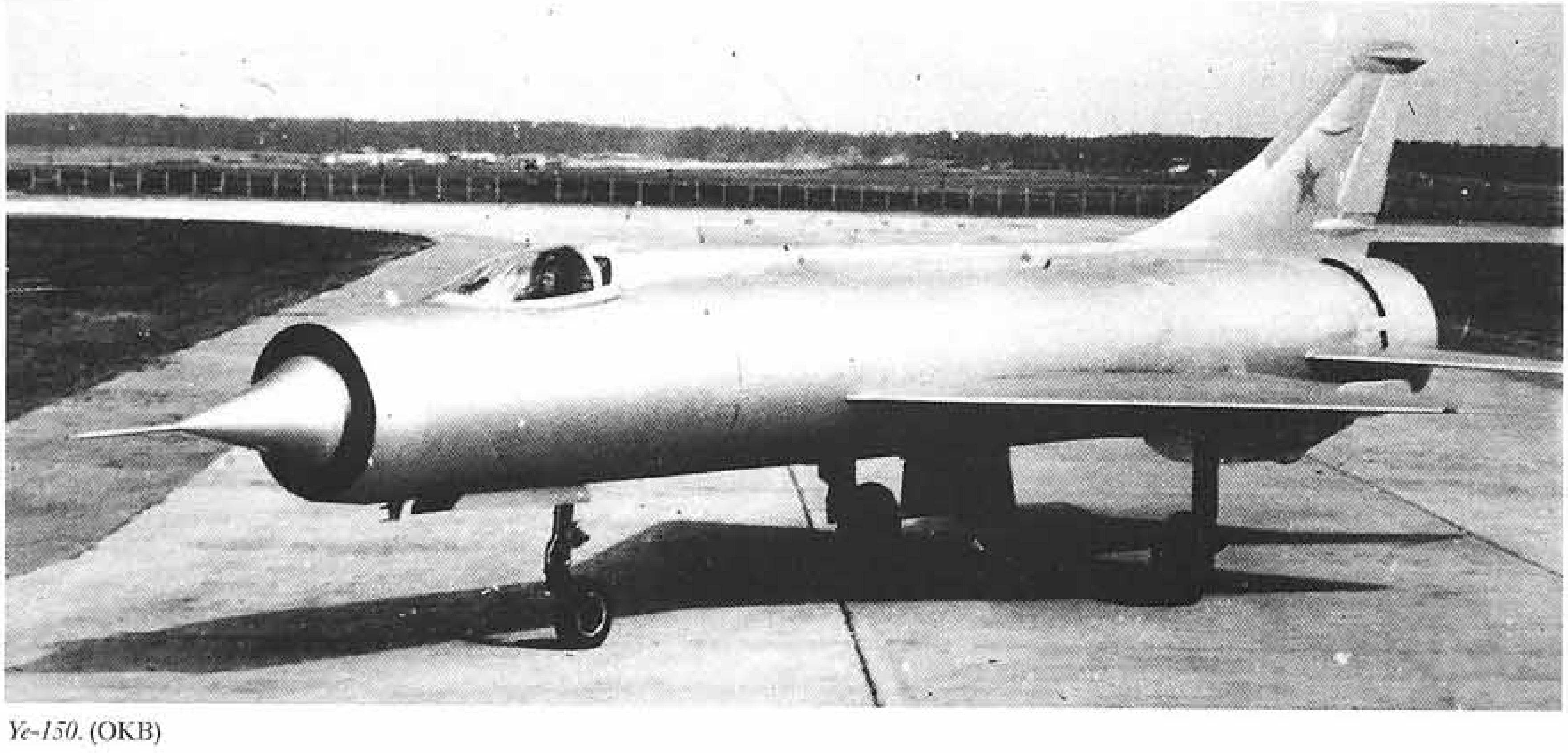
While Tumanskiy developed this engine the MiG OKB was ordered to build an aircraft in which it could be tested. This was quickly schemed by a team led by Nikolai Matyuk. For minimum drag it was a tailed delta, designated Ye-150. The contract was for a single aircraft. This was simply an engine testbed, though it was designed so that it could easily be developed into an interceptor, with an *Uragan*-5B radar and two K-9 missiles. Contrary to some reports, the Ye-150 itself was not designed to be armed; it was stressed to the low factor of 5.1, and its nosecone was metal.

The wing had S-9s profile, with a thickness/chord ratio of 3.5 per cent at the root, changing to 5 per cent at the tiny squared-off tip. Leading-edge angle was 60° (one document gives this as the ¼-chord angle). Each wing was set on the fuselage fractionally below midlevel, with the underside of each wing horizontal to give slight anhedral on the upper surface. The leading edge was fixed, and there were no fences, though the wing was so thin that the BU-75 power units for the ailerons required slim fairings above and below at the flap/aileron junction. Each aileron had an area of 1.56sq m (16.8sq ft) and had limits of ±20°. Inboard were rectangular tracked slotted (not Fowler) flaps, driven to a maximum of 25°.

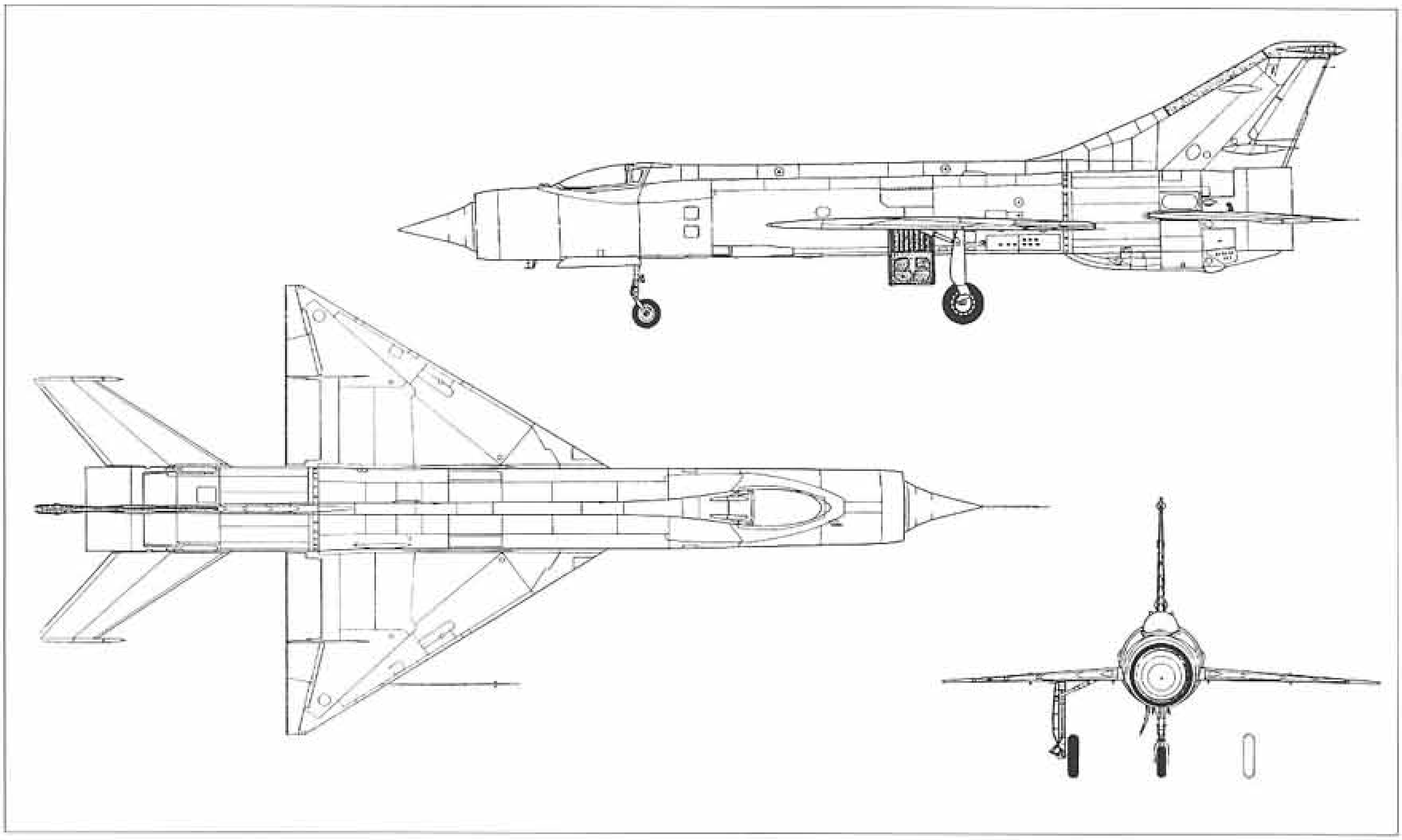
The fuselage was essentially a tube with the constant diameter of 1.6m (63in). The circular nose inlet housed a large Oswatitsch-type central cone. This was fixed to the splitter which diverted the ducts past the cockpit, variable-geometry being provided by the translatable inlet rim. As in the I-75, this was mounted on four hydraulic rams, and extended forwards automatically at all Mach numbers above 1.65. Each air duct contained two surge bleed and auxiliary inlet valves with almost square spring-loaded doors on each side of the fuselage. The ejector nozzle was fixed, but of course the primary nozzle was hydraulically operated (using fuel) to adjust area and profile to the operating regime. Five bladder tanks in the fuselage housed 3,720 litres (818gal) of fuel, augmented by a 245 litres (53.9gal) integral tank in the front of each wing, giving a total of 4,210 litres (926gal). Special high-capacity turbopumps supplied the afterburner.

The rods controlling the tail power units were housed in a dorsal spine. The vertical tail had a leading-edge sweep of 55°, S-11s profile with a thickness/chord ratio of 5 per cent, and area of 5.6sq m (60.28sq ft) for the fin and 1.09sq m (11.73sq ft) for the rudder, which was driven by a BU-75 power unit. The slab tailplanes again had a leading-edge angle of 55°, and S-11s profile, with thickness/chord ratio of 6 per cent changing to 4 per cent at the tip. They were larger than those of the I-75, with a span of 5.292m (17ft 4⅜in) and combined area of 6.5sq m (70sq ft). Each slab had an antiflutter mass at the tip, and was driven by its own BU-65 irreversible power unit.

Following OKB practice there were two slim rectangular airbrakes on the flanks of the fuselage under the trailing edge of the wing and a single door-type brake under the leading edge. Each had an area of 1.08sq m (11.6sq ft), and was driven to 45°. A heat-insulated box under the rear fuselage housed the single large (18sq m, 193.7sq ft) braking parachute. The landing gear was similar to that of the



Ye-150. (OKB)



Ye-150.

I-7/I-75, with a track of 3.322m (10ft 10.8in) and wheelbase of 5.996m (19ft 8in). The mainwheels were KT-69 with tyres 880 × 230mm and the nose unit a KT-78 (600 × 155mm).

For minimum drag the cockpit had a very small one-piece canopy moulded in 20mm-thick T2-55 glass designed to soak at maximum speed at up to 170°C. It hinged upwards at the front. The pilot seat was of the OKB's new KM-1 type, with a faceblind. A PVD air-data probe was mounted well out on the starboard wing, a duplicate pitot boom was mounted on the nosecone, and above and below the nose were a q-feel pitot and a telemetry antenna. Other antennas occupied the leading edge and cap of the fin.

The Ye-150 was completed in December 1958 and taken to the LII airfield near Ramenskoye named for Zhukovskiy. Here it was prepared for flight, but suffered repeated problems during ground testing. On one occasion it was even returned to the OKB factory. It returned to the airfield on 30 December 1959 and finally was cleared to begin its factory flight-test programme on 8 July 1960. By this time the Ye-152A, with more mature engines, had already been flying for a year.

The factory pilot assigned to the Ye-150 was A V Fedotov. On the fourth flight, on 26 July 1960, he experienced aileron flutter at about Mach 0.925 at 5,200m (17,000ft). This should have been impossible with irreversible power units; to prevent it, a damper was fitted in the drive mechanism. On the next flight the engine accessory gearbox cracked. Four successive R-15-300 engines were used in this aircraft. Because it was so much lighter than related interceptors it had tremendous performance, yet it was never used to set world records. The highest speed was reached on the 28th flight, after which the nozzle ejector was replaced and the cockpit heat-insulation improved. Tests resumed on 14 November 1961. Altogether the Ye-150 made forty-two test flights, ending on 25 January 1962.

Span 8.488m (27ft 10⅛in); length 19.3m (63ft 4in), (excluding probe) 18.14m (59ft 6⅛in), (fuselage, from inlet lip) 15.60m (51ft 2⅛in); wing area 34.615sq m (372.6sq ft).

Weight empty 8,276kg (18,245lb); internal fuel 3,410kg (7,518lb); weight loaded 12,435kg (27,410lb).

Maximum speed 1,210km/h (752mph, Mach 0.99) at sea level, 2,890km/h (1,796mph, Mach 2.72) at 19,100m (62,664ft); climb to 5,000m (16,404ft) 80sec, to 20,000m (65,617ft) 305sec; service ceiling 23,250m (76,280ft); range approx. 1,500km (932 miles); takeoff run 935m (3,068ft); landing speed 285km/h (177mph); landing run (with brake chute) 1,250m (4,100ft).

Ye-151 project

A full-scale mockup of the fuselage of this proposed day fighter was built to study how best to install TKB-495 guns. This 23mm weapon was specially designed to be mounted on pivots so that it could be elevated and depressed relative to the fuselage. Three had flown in the SN (MiG-17 derivative). In one arrangement, called Ye-151/1, the gun (apparently only one) was in the forward fuselage, fed with ammunition from a magazine behind the cockpit. As in the SN, it was judged that accurate aiming would be impossible because recoil would tilt the aircraft. With the Ye-151/2 the complete gun installation was mounted as near as possible to the centre of gravity of the aircraft.

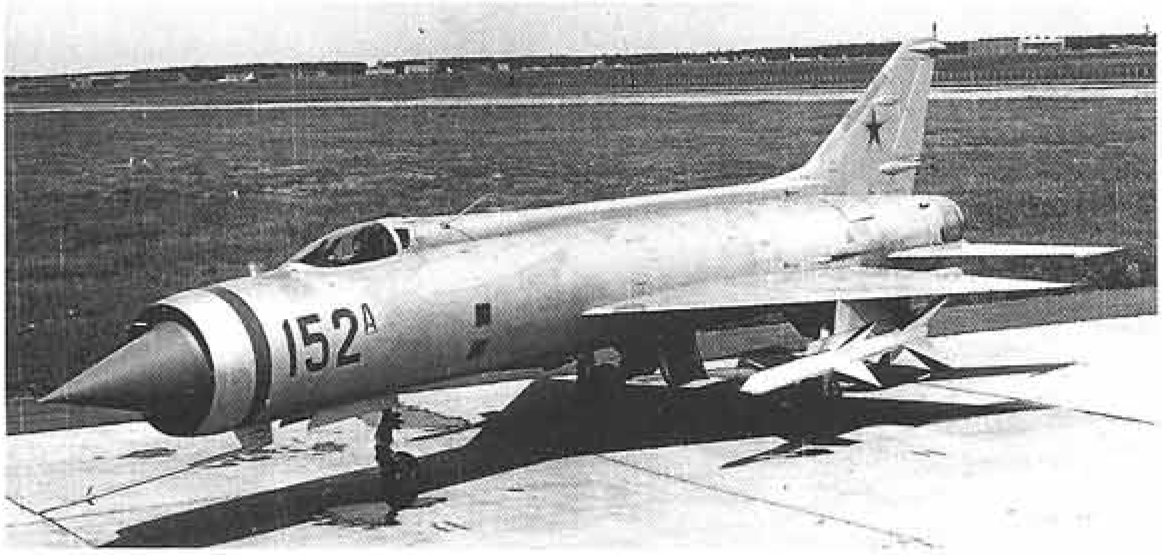
Neither aircraft was built, but it is stated that the Ye-151 forward fuselage was longer than that of the Ye-150, and that tunnel-tests showed that the greater length of air inlet duct improved the operation of the engine. This extended fuselage was therefore made standard, starting with the Ye-152A. In fact, OKB drawings and documentation show that the Ye-152A had a slightly shorter fuselage than previously; the long inlet was a feature only of the Ye-152, Ye-152P and Ye-152M.

Ye-152A

This single prototype was authorized in 1957–58 as a parallel project to the Ye-152. Unlike the Ye-150, it was to be an interceptor, and to reduce development risk it was designed to be powered by a pair of mature engines. These were Tumanskiy's R-11F-300, slim axial-flow turbojets developed from the engines of the MiG-19. Maximum dry rating was 3,880kg (8,554lb) and sea-level thrust in afterburner was 5,740kg (12,654lb). The engine had already been selected for such production aircraft as the MiG-21 and Yak-28.

Though based as nearly as possible on the Ye-150, the Ye-152A incorporated over one hundred modifications. The entire airframe was restressed to a load factor of 7, the fuselage was redesigned, and the whole aircraft was filled with upgraded systems, interceptor avionics and armament. The only items left almost unchanged were the landing gear and the wings, though the latter had midspan pylon attachments and inboard leading-edge antennas.

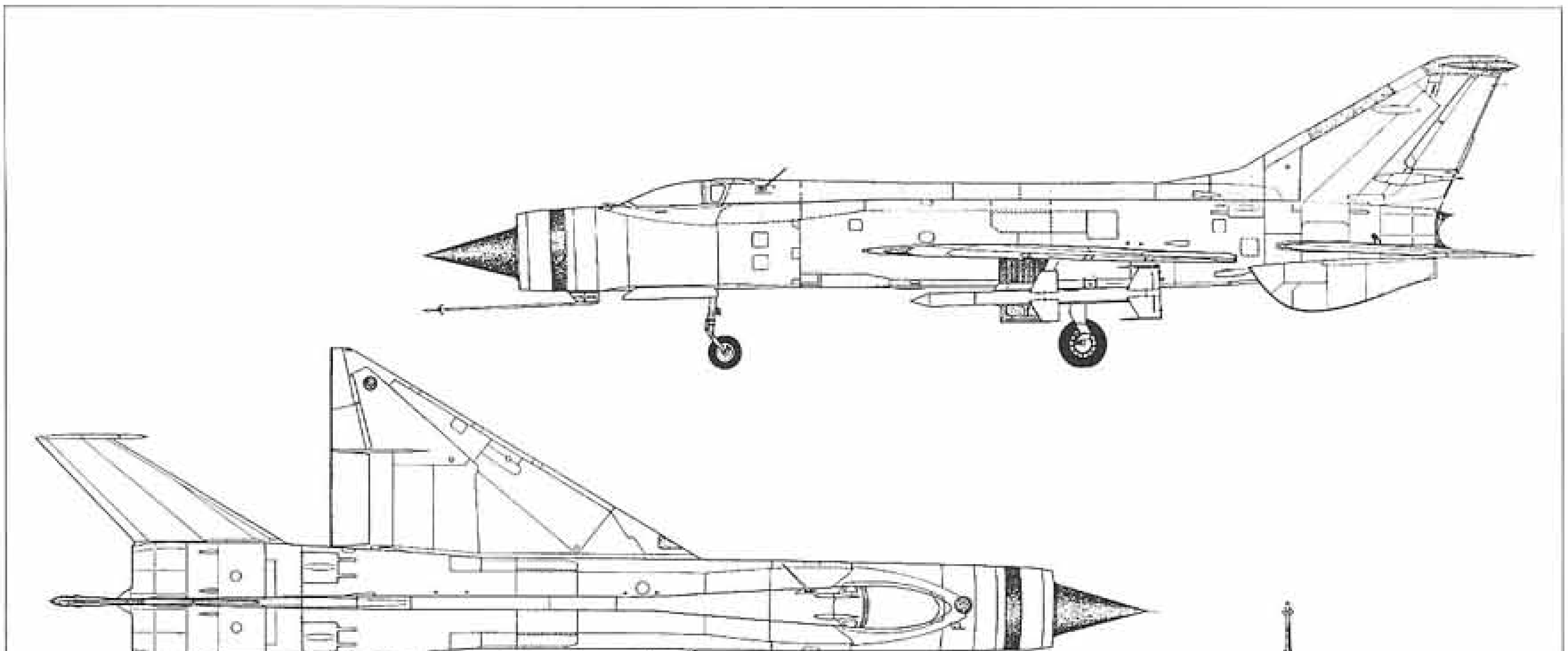
The nose inlet was modified with an enormous central cone, made this time of erosion-resistant glassfibre to make it transparent to radar signals, large enough to house the radar antenna and with a three-angle Oswatitsch profile to create weak shockwaves. The cone was fastened to the duct splitter and braced by lateral aerofoil struts. The surrounding inlet ring was of greater chord (axial length) than that of the Ye-150, and its four operating rams could translate it forwards to any of three axial settings depending on Mach number and q-feel dynamic pressure.



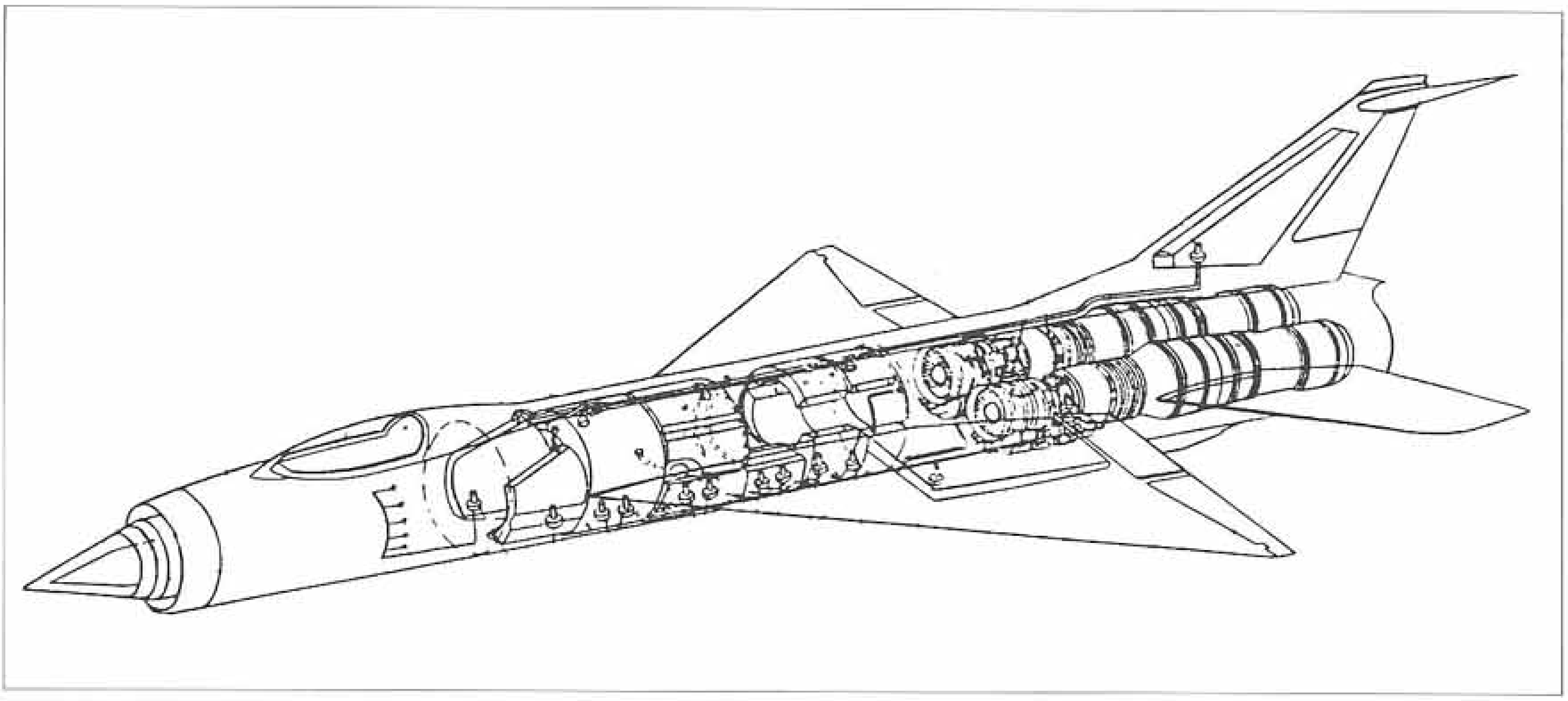
Ye-152A with mockup K-9 missiles. (Yefim Gordon archive)

Downstream of the cockpit the ducts swiftly curved in to form a central tube, as before, but this had to split again at the main-spar frame to feed the closely spaced engines. These were larger than the MiG-19 engines, inlet diameter being increased from 668mm to 825mm (32.5in). To accommodate them the rear fuselage swelled laterally into a flat oval, but the overall plot of cross-section areas was carefully area-ruled for minimum supersonic drag. Thanks to better secondary airflows and improved materials, each engine bay needed only two projecting cooling airscoops (compared with eight in some MiG-19s) and two to cool the generators. No nozzle ejector was fitted, and the titanium structure round the nozzles was extended aft in 'pen nib' fashion as in the MiG-19.

An accompanying OKB sketch shows the fuel system. Capacity was 4,400 litres (968gal) in six fuselage cells and two wing integral tanks. The



Ye-152A.

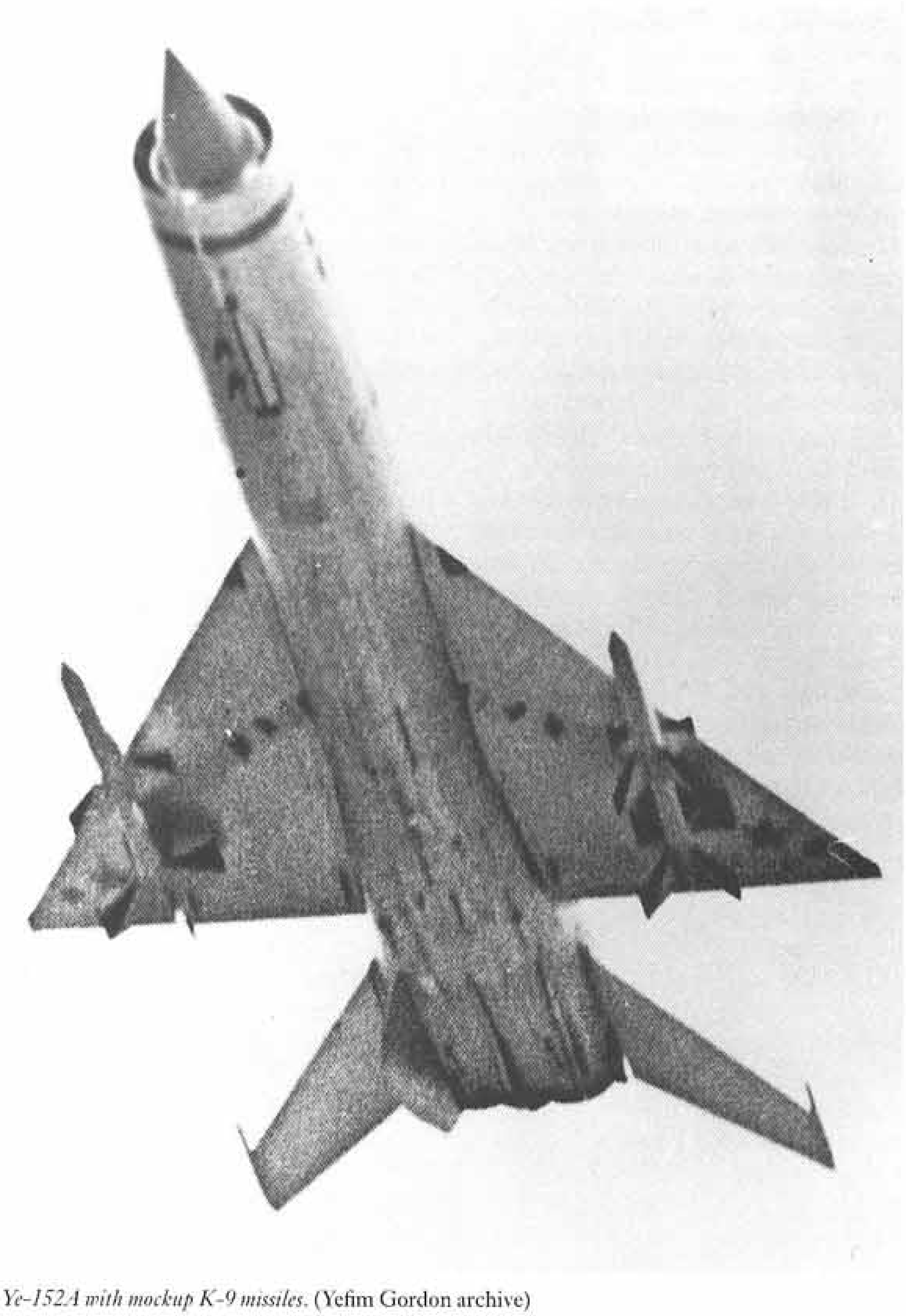


Ye-152A showing typical fuel system.

fin tank was introduced with the Ye-152. The system was refuelled from a rapid-flow pressure connection above Tank 3 just to the left of the fuselage spine. Along the bottom of the fuselage were jettison valves. In addition there was provision for a PB-1500 supersonic drop tank of 1,500lit (330gal) to be carried on a fuselage pylon, though weight limitations restricted drop-tank size to 600 litres (131gal).

Apart from extra avionic antennas the tail was identical with that of the Ye-150, though the wider fuselage increased tailplane span to 5.85m (19ft 2⅜in). In contrast, one of the most distinctive features of the Ye-152A was that under the rear fuselage were two very large diagonal underfins. Between them was the insulated compartment for twin I-75 type braking parachutes. The landing gear was almost identical to those of the immediate predecessors, though the nosewheel was Type KT-28 (600 × 155mm). Another completely new feature was that the rear pair of airbrakes were mounted on top of the rear fuselage, opening upwards on each side of the dorsal fin. A third brake was in the usual position under the fuselage near the wing leading edges. Air-data measurements were taken by a small q-pitot near the windscreen and a long PVD-7 boom mounted at negative incidence on a pylon under the first available fixed part of the nose.

Armament comprised two of the MiG-developed K-9 missiles, carried on deep underwing pylons at mid-semispan at –3° nose-down incidence.



Ye-152A with mockup K-9 missiles. (Yefim Gordon archive)

These had semiactive homing guidance provided by the new TsP radar, which was interlinked with the *Uragan*-5 ground-control system. For automatic interceptions the *Uragan*-5 signals were fed to the AP-39 autopilot after being processed by a computer called SRP, from Russian for 'count' (take measurements), 'decide' and 'equip'.

Other avionics reflected the fact that this was no mere testbed. The radio was the RSIU-4V, with an antenna mast projecting diagonally to the left from the fixed rear part of the canopy. The IFF was the SRO-2 *Khrom-Nikel*, with experimental flush antennas above the nose and on each side of the blister at the top of the fin. The radio compass was the ARK-541 (in some documents, ARK-54N), with new antennas ahead of the windscreen and in the leading edge of the fin. The air-traffic-control-selective-identification transponder, operating at decimetric wavelengths, was the SOD-57MU, with flush antennas in the fin skin immediately below the glassfibre cap. The interceptor-guidance beacon station was called *Meteorit*, with an aft-facing antenna in the trailing edge of the fin cap. Each engine drove a GSR-St-12000 generator to charge two 15STsK-50 batteries immediately ahead of the underfuselage airbrake.

Though started later than the Ye-150, the mature engines of the Ye-152A enabled it to fly earlier. Visually one of the most impressive aircraft ever built, it was rolled out in June 1959, unpainted. Later it received its painted designation (with letter A smaller than the rest) instead of a numerical callsign. Both Mosolov and Fedotov were assigned to test it, and the former made the first flight on 10 July 1959. Factory testing ended on 6 August 1960 after fifty-five very satisfactory flights, the first fifty-one clean, Nos. 52/53 with pylons and the final two with missiles. Ten engine relights were accomplished with no problem at heights up to 10,500m (34,450ft).

A further test programme was flown between 30 September and 23 November 1960. It made a flypast at the 1961 Tushino airshow, causing a sensation among Western observers and resulting in the ASCC name 'Flipper', and – because this was the next odd number after 21 – the announcement in Western media that it was the 'MiG-23'. The Ye-152A was then assigned to prolonged avionics and weapon tests, including missile firings until, in 1965, it crashed, killing OKB pilot Igor Nikolayevich Kravtsov.

Span 8.488m (27ft 10⅛in); length 19m (62ft 4in), (fuselage, from inlet lip) 15.45m (50ft 8¼in); wing area 34.02sq m (366.2sq ft).

Weight empty 8,740kg (19,268lb); internal fuel 3,560kg (7,848lb); weight loaded (clean) 12,500kg (27,557lb), (with missiles) 13,550kg (29,872lb), (plus 600lit tank) 13,960kg (30,776lb).

Maximum speed (clean) 2,135km/h (1,327mph, Mach 2.01) at 13,700m (44,950ft), still accelerating but limited by buffet and vibration; maximum Mach number with missiles 1.89; climb to 10,000m (32,808ft) 1.48min; service ceiling at Mach 1.88 19,800m (64,960ft); range not recorded; takeoff time and speed (afterburner, no flap) 21sec, 420km/h (261mph), takeoff run 1,200m (3,937ft), takeoff time and speed (flap) 360km/h (224mph), takeoff run 1,000m (3,280ft); landing speed 260km/h (161.5mph); landing run 2,018m (6,621ft), (with parabrakes) 1,600m (5,249ft).

Ye-152

This was intended to be the definitive 'heavy interceptor', combining the avionics and missiles of the Ye-152A with the powerful engine tested in the Ye-150. On the recommendation of the pilots, the wing was enlarged, which opened up various possibilities. OKB-155 received a contract for two prototypes, designated as the Ye-152/1 and Ye-152/2.

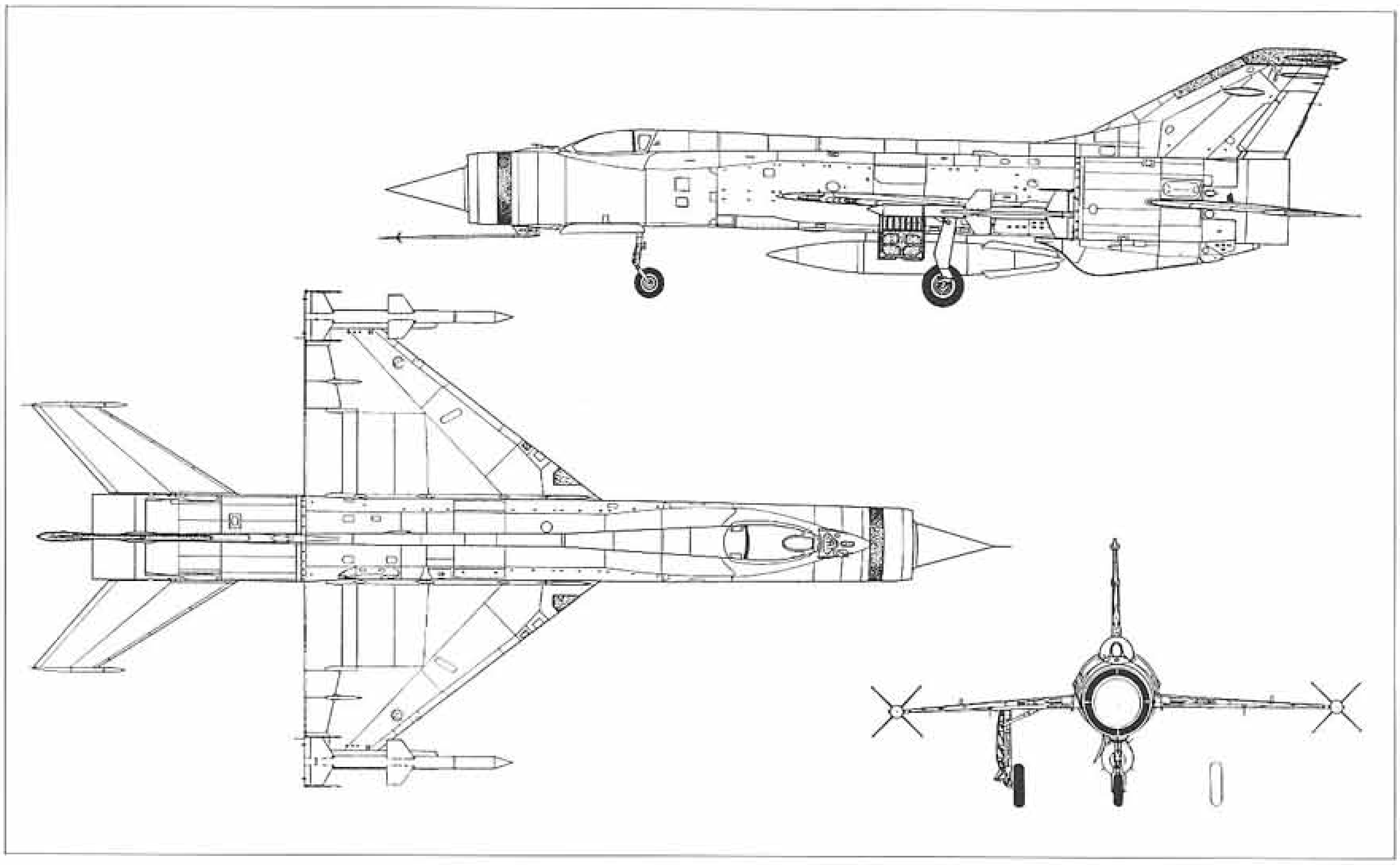
Much of the airframe was identical to that of the Ye-152A, though the circular-section centre and rear fuselage more nearly resembled the Ye-150. The obvious major difference was that the missile launch shoes were mounted on the wingtips. Less obvious was that, to increase fuel capacity and wing area, the fuselage was about 1m (39.4in) longer, with an extra frame increasing the root chord of the wing and another increasing the gap between the wing and tail.

Whilst retaining the same aerofoil profile and incidence, the new wings were set at –1° anhedral. The leading-edge sweep was reduced to 53°47′, which, together with an increase in span, combined with greater root chord to give a tip chord of 1.86m (6ft 1in). These changes automatically increased track to 4.2m (13ft 9⅜in), while the greater length increased wheelbase to 6.265m (20ft 6⅝in). This pleased the pilots by improving stability on the ground, making taxiing easier.

Stability in flight was also enhanced by increasing the chord of the vertical tail, to give a fin area of 6.9sq m (74.3sq ft), and replacing the underfins by a single ventral fin of even greater area than before. There were many other changes. The one-piece canopy was provided with an inserted optically flat windscreen. The inlet cone was provided with a band of perforations 0.3m (11.8in) wide around the cylindrical portion immediately downstream of the third (90°) shockwave. This was connected to aft-facing ejectors above and below the nose, just downstream of the translating inlet ring, which sucked out the cone's boundary layer and improved airflow to the engine. To change the engine the entire rear fuselage was detachable at the frame in line with the wing trailing edge. The nozzle ejector was faired into the rear fuselage, the induced air entering through four large circumferential slots.

The modified outer wings facilitated redesigning the ailerons as single surfaces, of reduced span but much greater chord. Each was driven by a BU-120M power unit, more powerful than the BU-75, acting not at the inboard end but at the centroid of the surface to give minimum distortion and eliminate the flutter previously encountered. Aspect ratio of the rudder was also reduced, and it was moved downwards and driven by a BU-120M. The two rear-fuselage airbrakes were omitted, and beside the ventral fin was fitted a box for a single large PT-5605-58 brake chute. The landing gear was similar to the Ye-152A but with KT-69/4 mainwheels and a KT-93 nosewheel.

As before, the Main and Utility hydraulic systems used AMG-10 mineral oil, and operated at 210ata (3,087lb/sq in). The engine drove a pump in each system, as well as a large GSR-St-105 generator charging four 15-STsS-45 batteries ahead of the single airbrake. The fuel system was modified to increase capacity. In the fuselage were Tank 1 (550 litres), Tank 2 (1,100 litres), its opposite number Tank 3 (1,120 litres), Tank 4 (120 litres), Tank 5 (460 litres) and Tank 6 (380 litres), and the wing integral tanks added 300 litres each in front of the front spar and 315 litres each behind it. This gave a total capacity of 4,960 litres (1,091gal), of which 4,850 litres (1,080gal) were usable. As before,



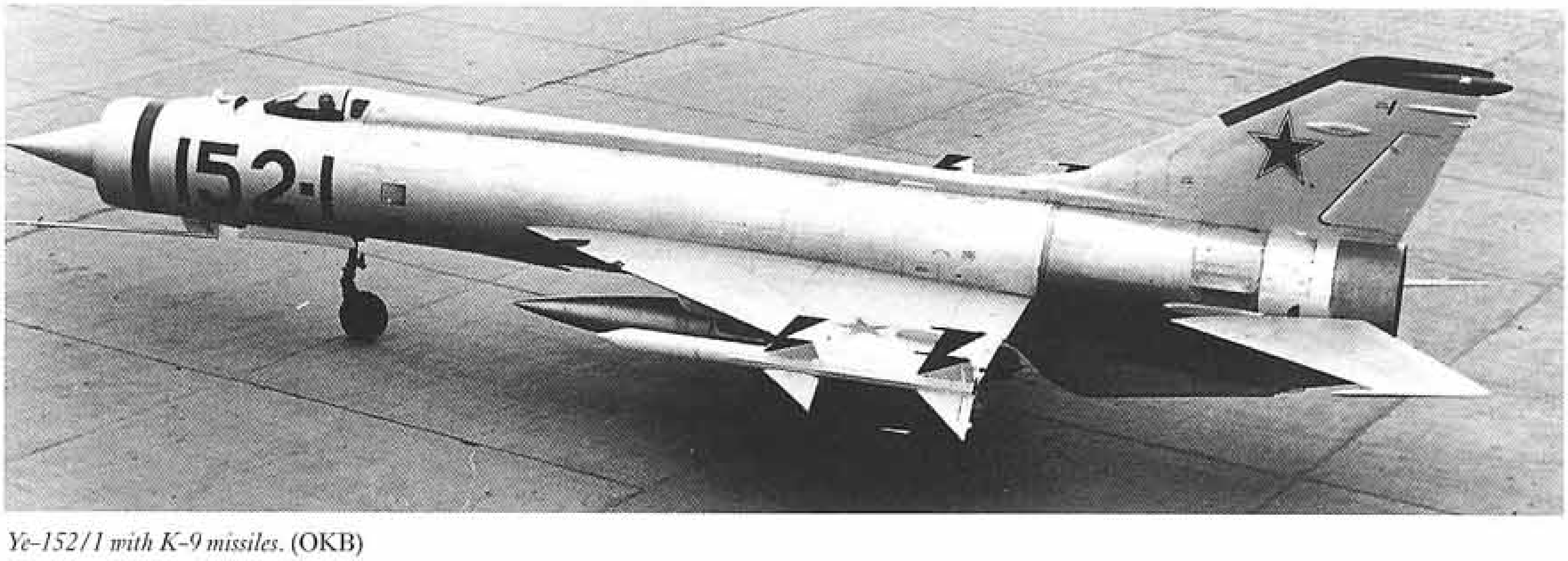
Ye-152/1.

provision was made for a supersonic drop tank of 1,500 litres capacity, but it is believed this was never fitted.

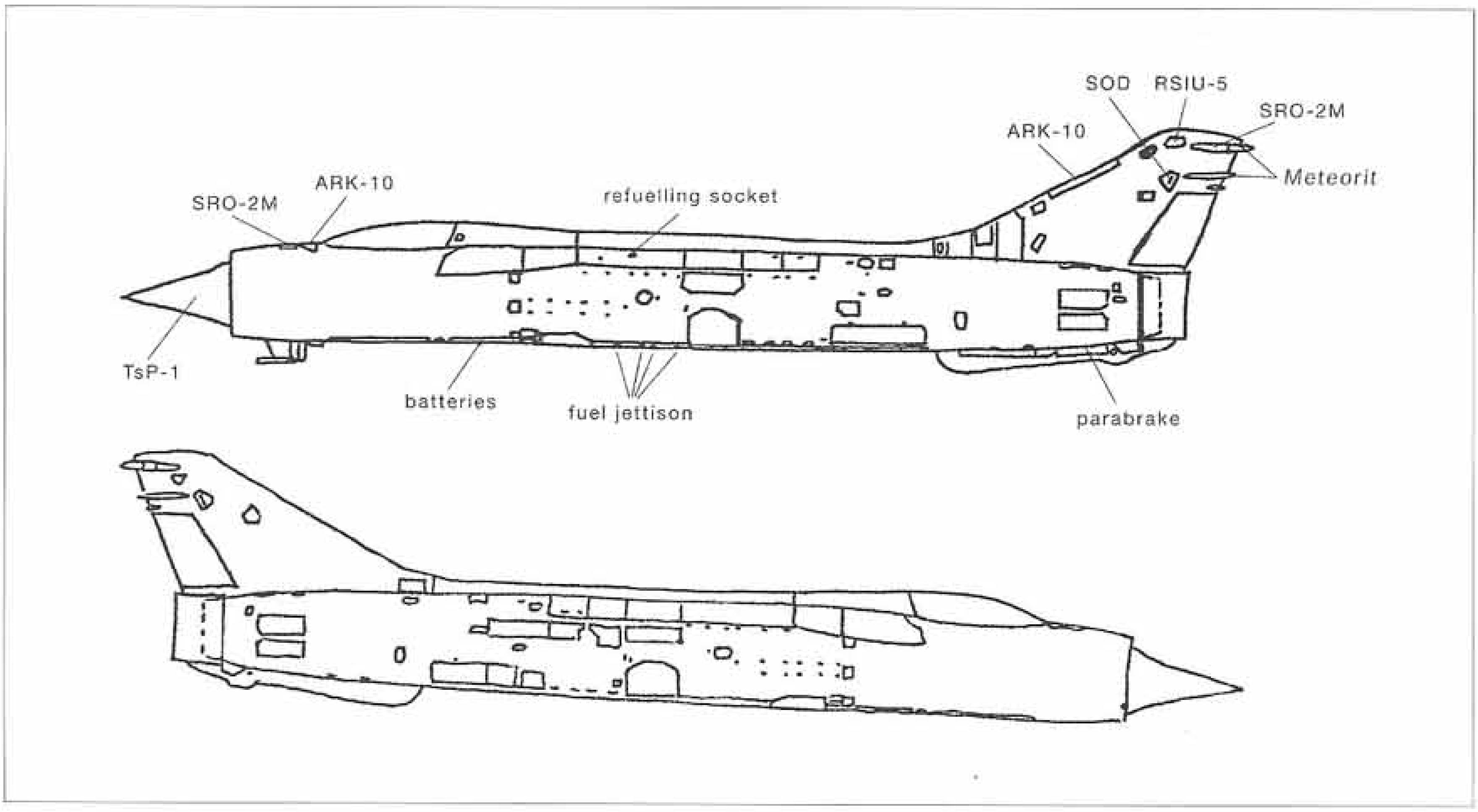
The K-9 missiles were carried on launch shoes at –1° incidence centred on the tip of each wing. Tunnel tests showed that this was a low-drag position and that the presence of the missiles could be beneficial to flow over the wing. The radar was again an *Uragan*-5B, and other avionics included four new items. The main radio was an RSIU-5 uhf with the antenna inside the fin cap, the IFF was an SRO-2M with a flush antenna in the upper ejector above the nose, and the *Meteorit* installation included SA-30, SPK and the SOD-57MU, all in the top of the fin, which was broader than before. Forward-facing SOD antennas were in the wing leading edge.

The Ye-152/1 was rolled out in early 1961, with an R-15-300 engine with the afterburning rating slightly increased to 10,210kg (22,509lb), the same as the improved R-15B-300. It arrived at the LII airfield on 16 March 1961, with ballast replacing the radar. In all its photographs it has a bold '152-1' on the forward fuselage and K-9 missiles on the launch shoes. It was first flown, by Mosolov, on 21 April. Factory testing was plagued by unreliability of the five engines fitted, but the Ye-152/1 proved to be the fastest of the family, and one of the fastest aircraft in the world at that time.

On 7 October 1961 Mosolov set an FAI-ratified world record for a 100km closed circuit at 2,401km/h (1,492mph, Mach 2.26). On 7 June 1962 the same pilot set a 15/25km straight-line record at 2,681km/h (1,666mph, Mach 2.52). Even this was considerably slower than the fastest level speed reached during Ye-152/1 testing. On 11 September 1962 Ostapenko set a sustained-altitude record at 22,670m (74,377ft). These records were reported to the FAI as having been set by an aircraft called 'Ye-166',



Ye-152/1 with K-9 missiles. (OKB)



Ye-152/1 drawing from OKB documents.

powered by an 'R-166' engine. Later the Ye-152M, which never set any records, was presented to the world as the 'Ye-166', with the records inscribed on its fuselage.

The Ye-152/1 made sixty-seven factory flights, fifty-one clean (a small crack appeared in the rear fuselage on flight No. 44), eleven with launch shoes and the final five with missiles. Testing was discontinued on 11 September 1962, the day of the altitude record.

Span 8.793m (28ft 10⅛in), (over missiles) 10.41m (34ft 1⅞in); length overall 20.475m (67ft 2in), (excluding PVD-7) 19.656m (64ft 5⅞in), (fuselage, from inlet lip) 16.603m (54ft 5⅝in); wing area 42.02sq m (452.3sq ft).

Weight empty 10,900kg (24,030lb); internal fuel 4,150kg (9,149lb); weight loaded 14,350kg (31,636lb), (maximum, not including PB-1500 tank) 14,900kg (32,848lb).

Maximum speed 3,030km/h (1,883mph, Mach 2.85) at 15,400m (50,525ft); speed with missiles 2,650km/h (1,647mph, Mach 2.495) at 16,200m (53,149ft); climb to 10,000m (32,808ft) 4.75min, to 20,000m (65,617ft) 8.83min; service ceiling 22,680m (74,409ft); range (estimated clean) 1,470km (913 miles); takeoff speed (14,730kg, afterburner and flap) 340km/h (211mph), takeoff run 1,145m (3,756ft); landing speed (11,000kg, parabrake) 270km/h (168mph); landing run 1,270m (4,167ft).

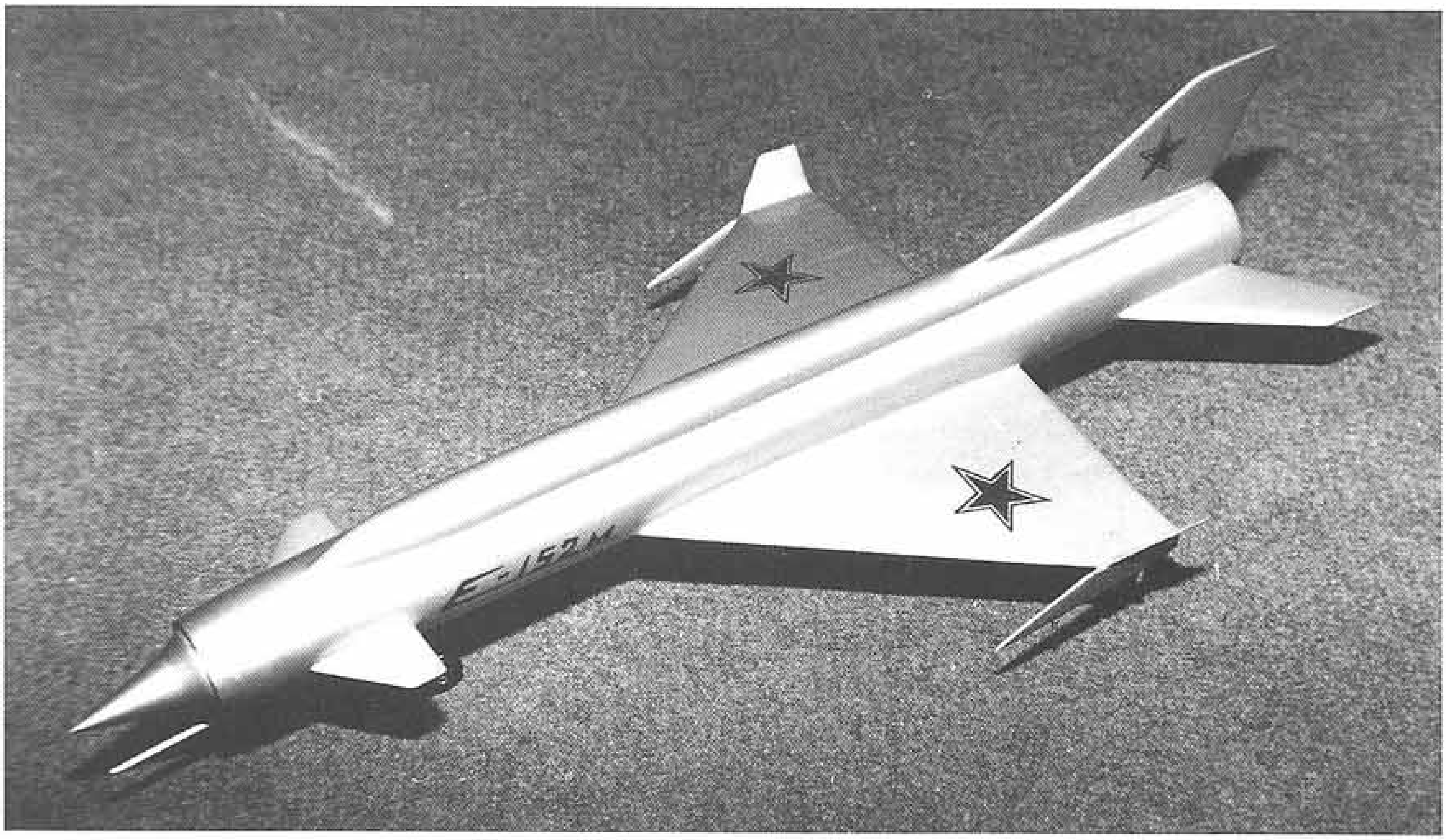
The Ye-152/2 was a *dubler* (second copy), though it differed in important respects. It was intended to be equipped with the *Smerch* (whirlwind) radar fire-control system developed by the Volkov KB. It proved impossible to fit this into the available space, though the associated K-80 missile could be mounted on the wingtips. The inlet was modified with a longer perforated section round the centrebody, to extract more boundary-layer air. The sequence in which fuel was drawn from the six fuselage tanks (of slightly reduced 4,930lit capacity) was changed to increase the pitch stability margin. The seat was the new SK-2, the canopy resembled that of the Ye-152A but without a fixed transparent rear portion, the generator was a GSR-St-105/18B and the batteries were a pair of 15STsS-50s.

The Ye-152/2 was assigned to Fedotov and to Piotr Ostapenko. They began factory testing on 21 September 1961 but the programme was abandoned on 3 July 1962. The Ye-152/2 was then converted into the Ye-152M. No data are available, apart from the fact that 2,740km/h (1,703mph, Mach 2.58) was reached clean, at the remarkable height of 22,500m (73,819ft), and Mach 2.28 (about 2,424km/h, 1,506mph) with missiles.

Ye-152M, Ye-152P

This replaced the Ye-152 as the definitive interceptor of the family, intended to carry *Smerch* radar and Bisnovat K-80 missiles. It also differed in other important respects from the previous Ye-152 prototypes. The engine was the R-15B-300, with maximum dry and afterburning ratings of 7,500kg (16,534lb) and 10,210kg (22,509lb). This was fitted with an improved variable nozzle, which when opened with the afterburner in operation had a convergent and then divergent internal profile, and the surrounding ejector was removed. Along the top of the fuselage was a large spine, which in addition to the tail control rods housed three additional fuel tanks housing (from cockpit to fin) 750, 630 and 380 litres, a total of 1,760 litres (387gal). As in the MiG-21, addition of this spine did not interfere with the area-ruling. On the forward fuselage were to be canard foreplanes of 3.5m (11ft 5¾in) span, with a root chord of 1.872m (6ft 1¾in) and a sharp-edged trapezoidal section, carrying antiflutter rods projecting ahead at midspan. These were to be fully powered, and were tested on a slightly smaller scale on the Ye-6T-3 (one of the MiG-21F prototypes). The dorsal fin was enlarged, with a long tubular fairing at the leading-edge kink.

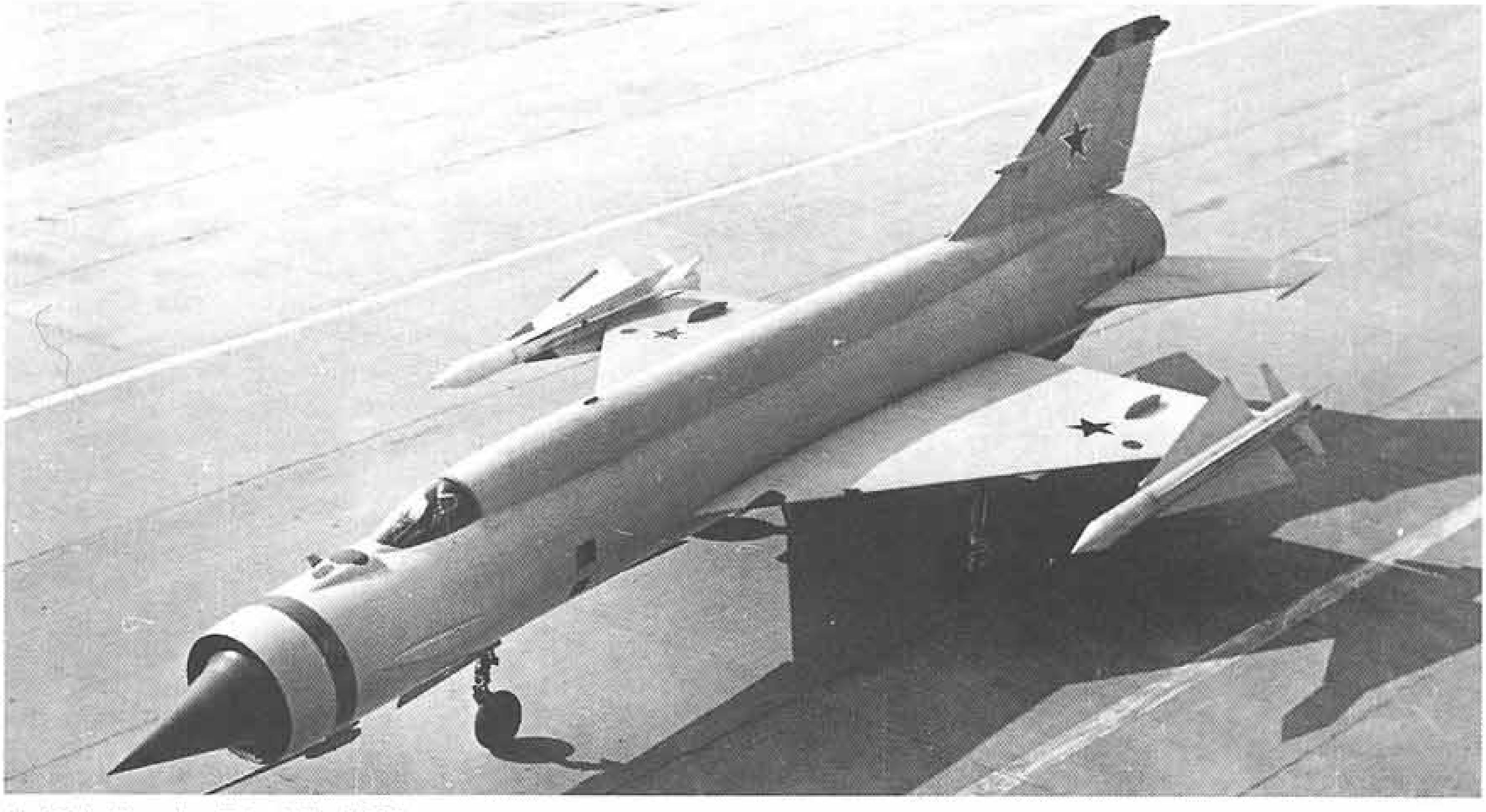
As a stepping-stone to the Ye-152M the Ye-152/2 was rebuilt as the Ye-152P. This was an experimental interceptor with almost all the airframe modifications intended for the Ye-152M, apart from the foreplanes where



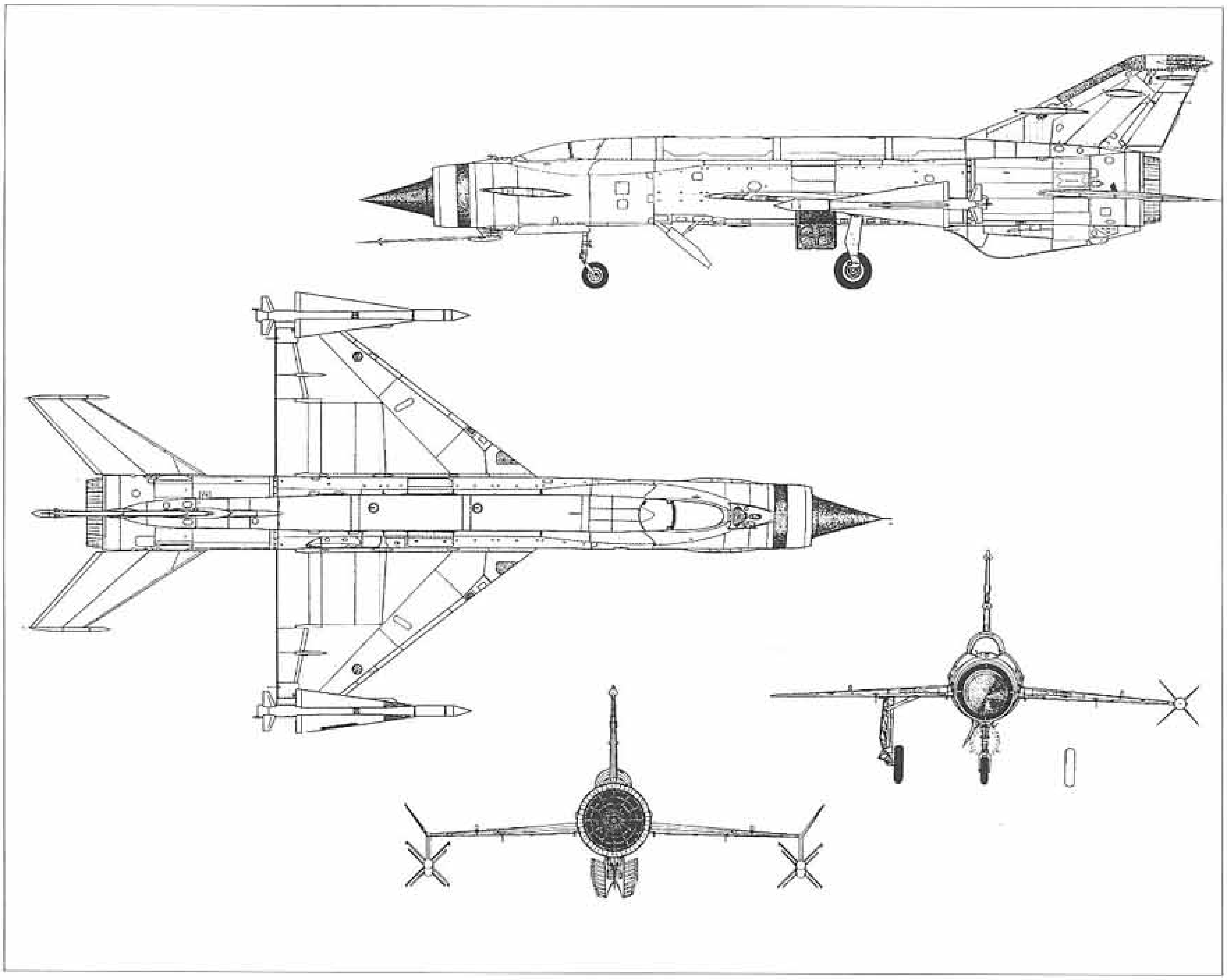
Model of Ye-152M. (photograph by Yefim Gordon)

only the fixed root mountings were fitted (at a remarkable positive incidence). In the nosecone was ballast, and on the wingtips were launch shoes for ballistically correct dummy K-80 missiles. A new upwards-hinged canopy was installed, with a clear front with no optically flat windscreen and with a metal rear section mating with the spine. The only other modification was to add a small fence underneath each wing at the flap/aileron junction (shown best in the Ye-152M drawings). Data indicate provision for a PB-1500 supersonic drop tank, but the Ye-152P is not known to have flown with this.

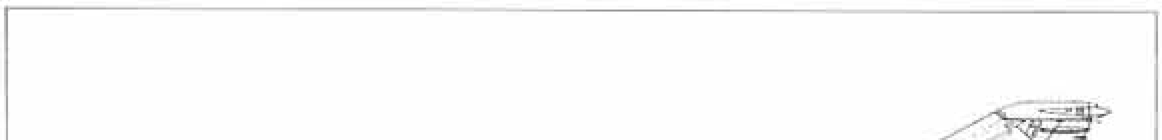
Tunnel testing indicated that when carrying the large delta-winged K-80 missile the torsional stiffness of the wing might prove inadequate. It was shown that at high indicated airspeeds the missiles could flutter, resulting in the initial launch trajectory being unpredictable. The OKB sought solutions in totally different geometry, including carrying the missiles well below the tip on a deep pylon and with



Ye-152P with mockup R-4 missiles. (OKB)



Ye-152P.

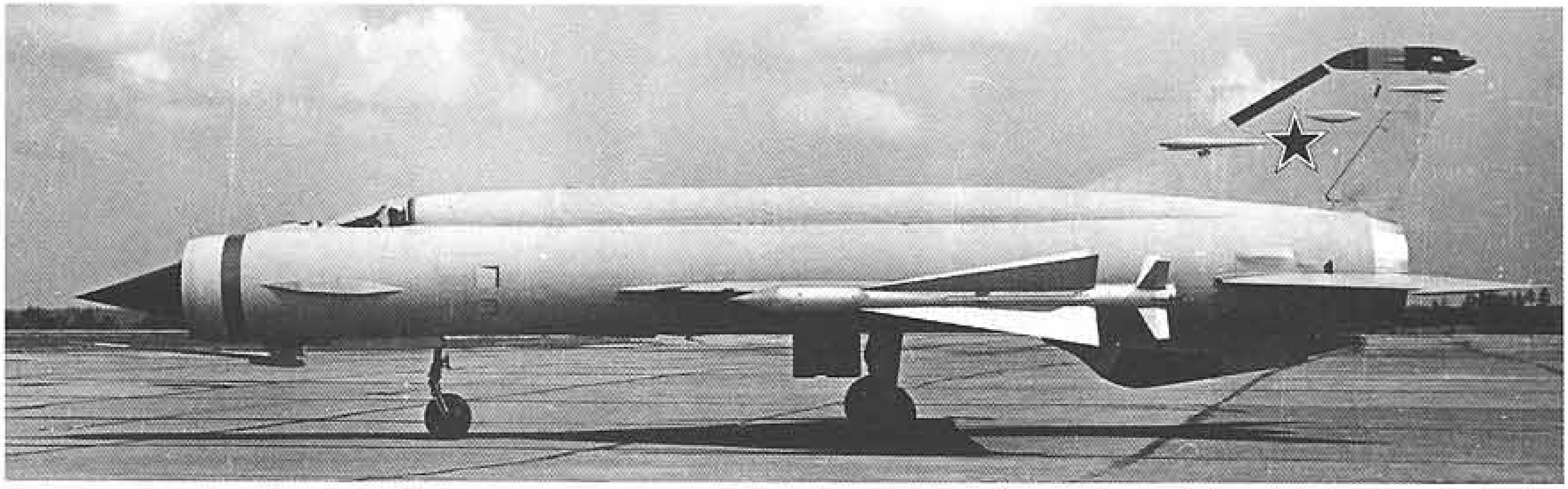


Ye-152M (fictitious 'Ye-166'), with extended tips.

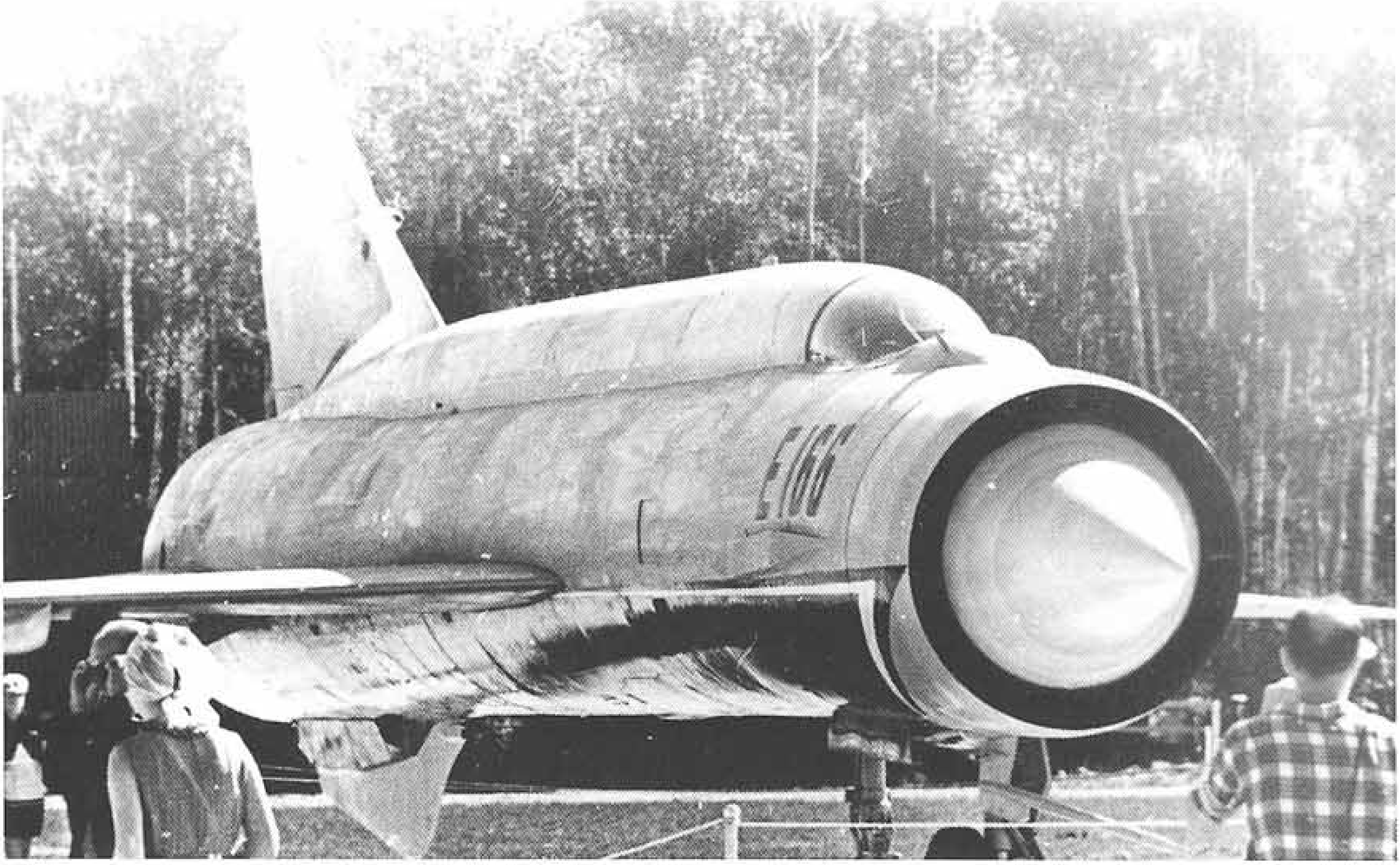
the wingtips extended upwards at 63° in the form of a winglet. This is shown in a model photograph and in the tail-on view in the Ye-152P drawing. For aerodynamic and structural reasons this idea was abandoned.

No dates have been found for the Ye-152P. All that is known is that it was painted white, and that at high indicated airspeeds the missiles did flutter. By 1963 the IA-PVO had ordered the much larger Tu-128 into production as its heavy interceptor, armed with various types of R-4, the production missile derived from the K-80. Meanwhile, the MiG OKB had begun work on the much more promising Ye-155 twin-engined interceptor.

The MiG single-engined 'heavy interceptors' thus became redundant. The Ye-152P was modified as the Ye-152M by removing the missile launchers. Later it was fitted with extended horizontal wingtips to give a wing plan similar in shape to the Ye-150, 152A and MiG-21. It never flew with these extensions. Instead, in 1967



Ye-152P with mockup R-4 missiles. (OKB)



Ye-152M at Domodedovo; spurious Ye-166 looks like 'E-166'. (Yefim Gordon archive)

it was painted in a red/white display scheme, 'Ye-166' was painted on it and it was adorned with three small red stars and details of the records set by the Ye-152/1. It was then exhibited at Domodedovo airport as the record-breaker. For the past thirty years the Ye-152P has been stored at the VVS museum at Monino.

Span 8.488m as before; (with extensions) 10.3m (33ft 9½in); length (from tip of cone) 19.656m as Ye-152, (from inlet lip) 16.35m (53ft 7¾in); wing area (without tip extensions) 42.89sq m (462sq ft), (with extensions) 44.5sq m (479sq ft).

Weight empty (Ye-152P) 11,440kg (25,220lb); fuel (internal) 5,420kg (11,948lb), (with PB-1500) 6,800kg (14,991lb); weight loaded 18,469kg (40,716lb).

Performance, not recorded, but claimed to have equalled the Ye-152/1 records of 2,681km/h and 22,670m sustained height.

MiG-21

Possibly the most famous of all Soviet aircraft, this small fighter was from the start severely limited in capability, simply because of its small dimensions and restricted space for avionics and weapons. Despite this, its performance, agility, price and all-round simplicity resulted in its adoption by fifty-six air forces around the world. This is likely to remain an all-time record, as is (for a post-1960 aircraft) the MiG-21's production total, including foreign manufacture under licence, of some 13,500. Not least of its achievements is that so far it has seen action in at least thirty shooting wars. In each of these records no other fighter even comes close, showing that from a commercial point of view the OKB got it absolutely right.

As the first significant conflict to involve jet fighters, the Korean War, from June 1950 to July 1953, was studied intently by Soviet fighter designers. They examined every engagement, especially those between the MiG-15 and North American F-86. While the MiG designers pressed ahead under the most intense pressure with the MiG-19 and other major programmes, the Kremlin crystallized the Korean experience into a single requirement for a new fighter, issued in autumn 1953.

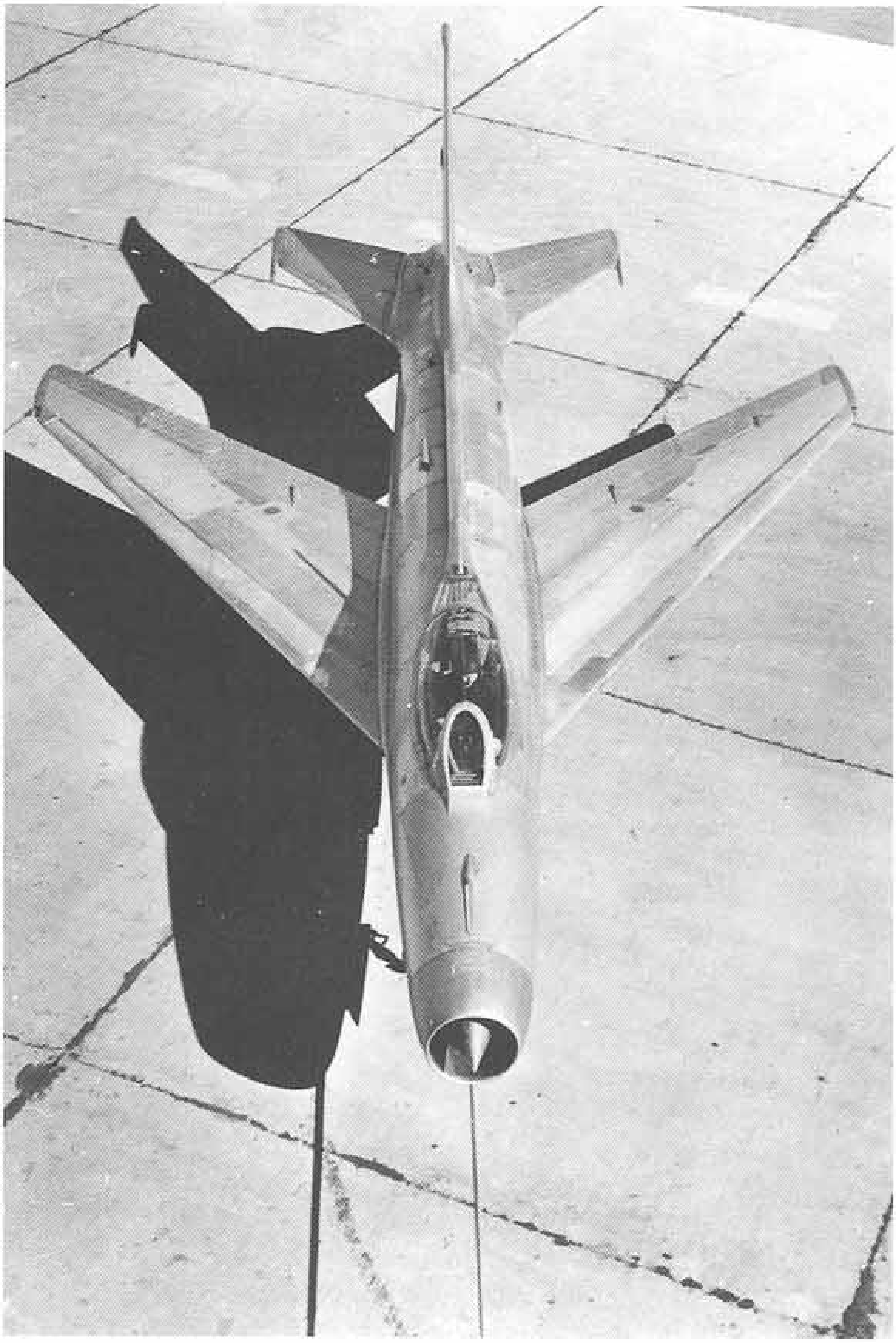
Wisely, the Kremlin refrained from calling for a long list of precise numerical demands. Instead it asked for 'a frontal fighter [i.e., not a radar-equipped interceptor] with a level speed of Mach 2 at an altitude of 20km (65,617ft) whilst carrying guns and a radar-ranging sight'. It was to operate under the *Markham* ground-control system to solve navigation and interception problems, and it was later to be capable of carrying guided missiles.

Mikoyan was determined not to be beaten with this requirement, and very quickly gathered the strongest possible design team. They quickly settled on the basic outline shape of a new small fighter, based on their established principles such as a wing mounted just below midlevel and attached on strong ring frames with no spars inside the fuselage. They also agreed to use the AM-11, then about to be tested by S K Tumanskiy in the Mikulin engine bureau.

The big question concerned the shape of the wing. With the assistance of the Central Aero-Hydrodynamics Institute (CAHI) they planned two prototypes as similar as possible, but with different wings. The tailless delta, as adopted by the French Mirage and many other aircraft, was rejected at an early stage, and the choice narrowed to either a slender swept-wing broadly similar to that of the MiG-19, but smaller, or to a pure triangle (commonly known as a delta in the West, but called *balalaika* in the USSR) used in conjunction with a swept horizontal tail.

By 1954 these two basic configurations had proliferated into the following projects:

OKB designation	Wing shape	Engine
Ye-1 or Kh-1	swept	AM-5A
Ye-1A or Kh-1A	swept	AM-9Ye plus S-155 booster rocket
Ye-2 or Kh-2	swept	AM-9B
Ye-2A or Kh-2A	swept	AM-11
Ye-4 or Kh-4	delta	AM-9B
Ye-5 or Kh-5	delta	AM-11



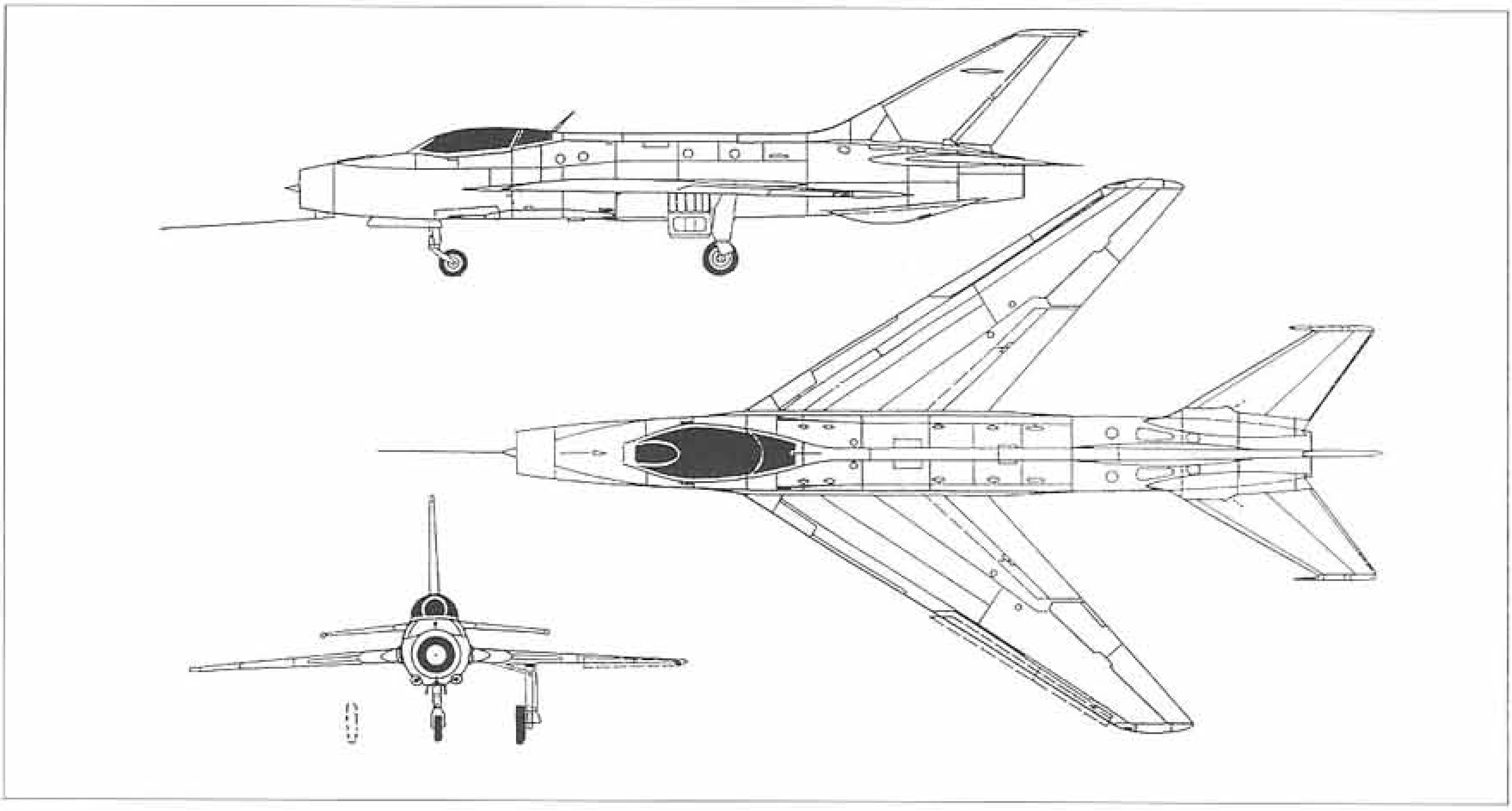
Ye-2. (OKB)

It was quickly decided that a single Mikulin bureau AM-5A engine was insufficiently powerful for a useful fighter, and the Ye-1 was abandoned. So important was this programme considered that contract cover was quickly obtained for all the other configurations. The Ye-2 was timed first, followed by the Ye-4, Ye-5, Ye-2A and, with the new designation Ye-50, the Ye-1A. To avoid repetition, the following is a brief description of the Ye-2.

Ye-2

This aircraft was based on a simple airframe made almost entirely of D16 and other common aluminium alloys, but with spar booms of V-25 and V-65-1 and with highly stressed joints made of special chrome steels such as 30KhGSA and 30KhGSN2A. The design load factor was 7, as were all the related prototypes.

The wing had a CAHI S-12s profile changing at the tips to SR-7s, with a thickness/chord ratio of 6 per cent

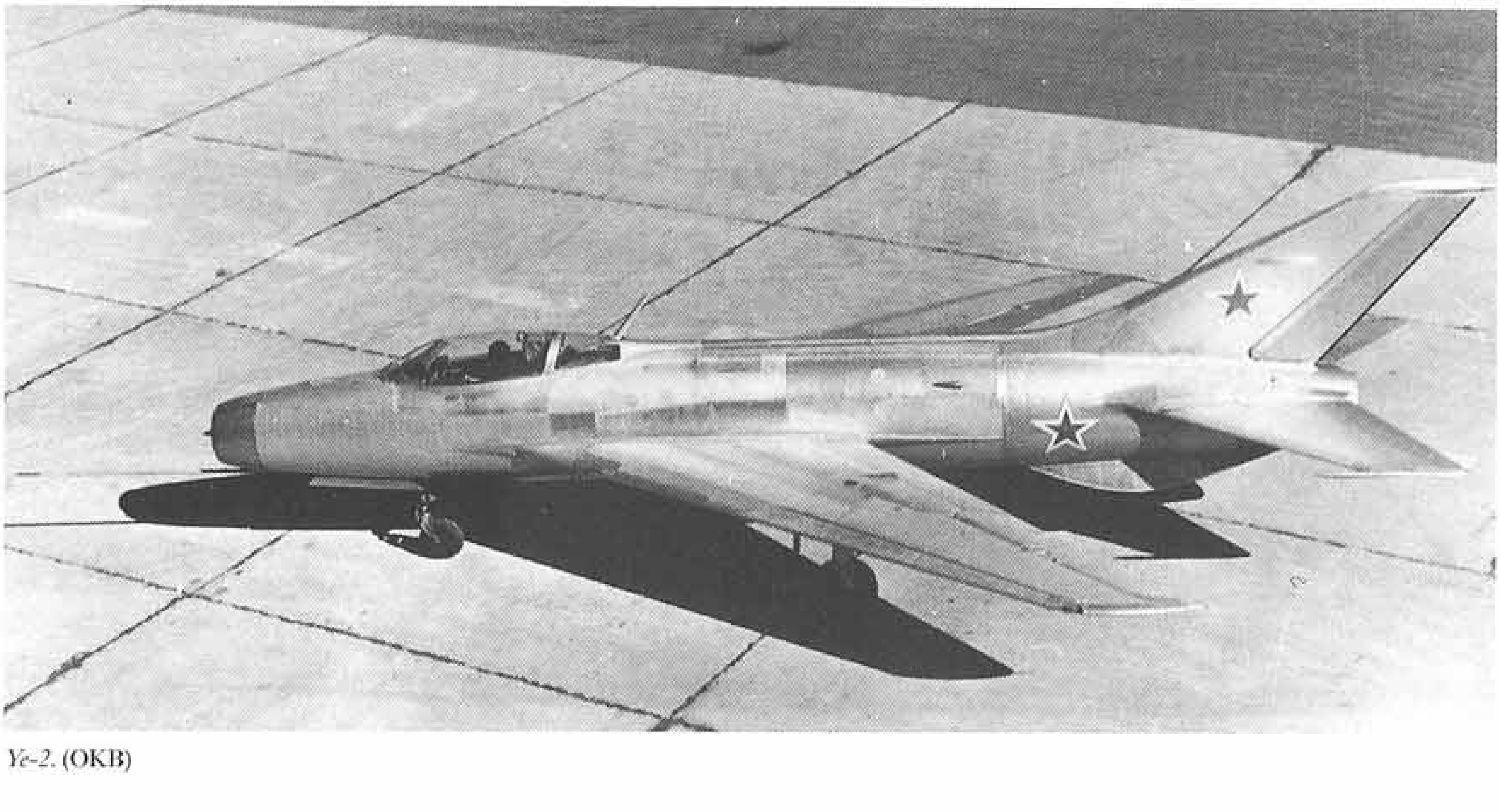


Ye-2.

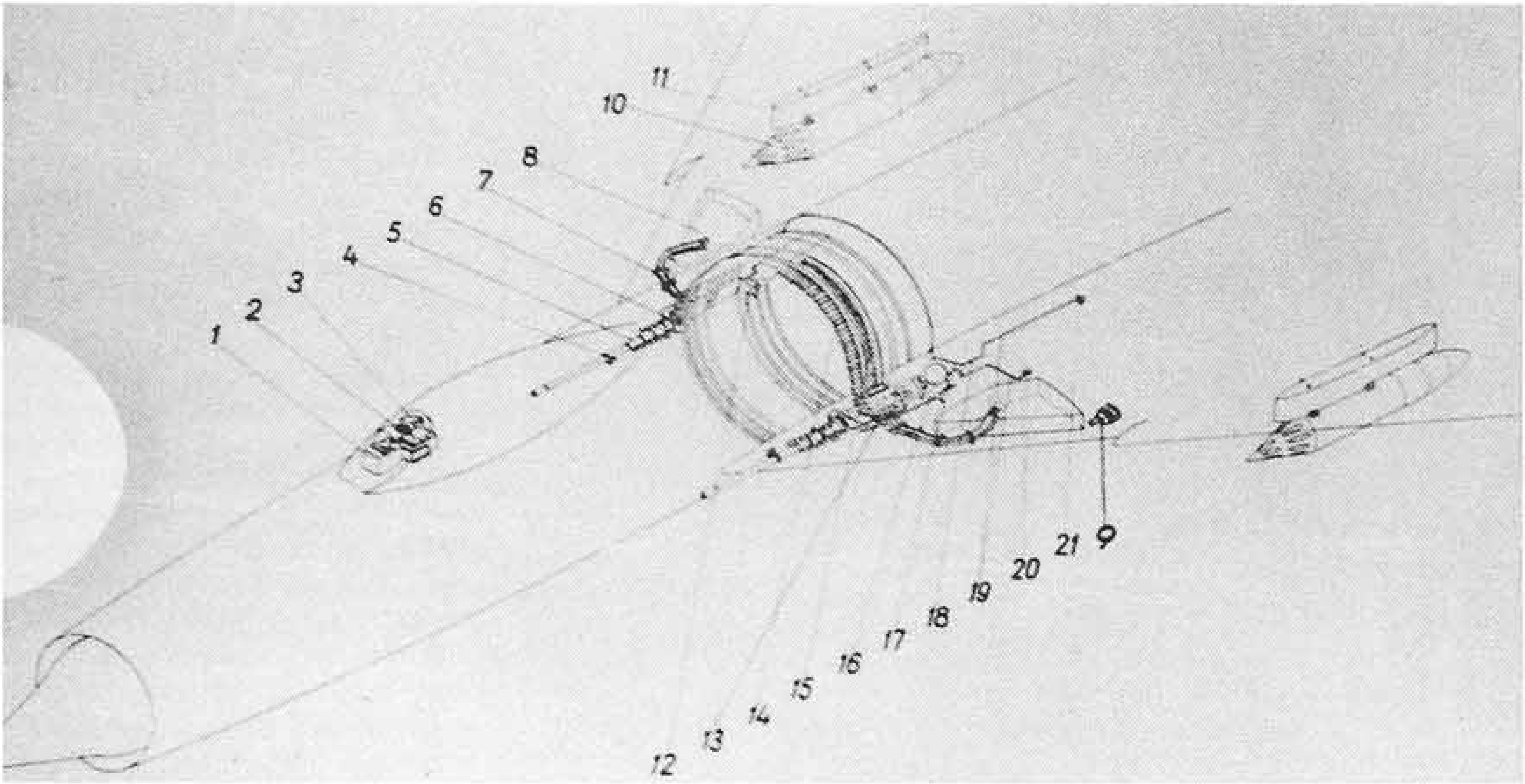
(thinner than the MiG-19). The leading edge had a sweep angle of 57° and the outboard half (ahead of the ailerons) was fitted with automatic two-part slats. There were no fences, and the wing was set at zero incidence with anhedral of –3°. It was not attached direct to the fuselage but to a streamlined platform integral with the forged root rib which projected ahead of and behind the wing.

Structurally, there were two spars forming a torque box from root to tip, with a third spar between them at the root terminated at Rib 8, all ribs being at 90° to the leading edge. Behind the torque box were tracks for the slotted flaps, each made in one piece and driven hydraulically to 40°. Outboard were the tapered two-part ailerons of sophisticated design, with balance area ahead of the hinge axis and interlinked to an undersurface spoiler. Each was driven by a BU-45 power unit, and the port inboard aileron had an electrically driven trim tab.

The fuselage was of oval section, with a ruling width over the central portion of 1.1m (43.3in), slimmer than any preceding MiG jet and considered the minimum to accommodate the ejection seat and engine. It followed the established design, with a sharp-edged circular nose inlet housing a small central cone mounted on the splitter which divided the air ducts past the cockpit. Unlike previous MiG aircraft, while the inlet itself was fixed, the central



Ye-2. (OKB)



Ye-2 armament; note suggested rocket launchers and leading-edge dogtooth, not adopted. (RART/GP)

cone could translate, being moved forwards by a hydraulic ram to an intermediate position at Mach 1.5, and then pushed fully forwards at Mach 1.9. Behind the rear pressure bulkhead at Frame 12 the ducts reunited to feed the AM-9B engine, rated at 2,600kg (5,732lb) maximum dry (MIL) thrust and 3,250kg (7,165kg) in afterburner. The inlet and ducts were sized to suit the more powerful AM-11, when this became available. At Frames 28/28A the bolted joint to the rear fuselage could be disconnected to change the engine. The rear fuselage tapered mainly from the top and ended in line with the trailing edge of the tailplanes, well behind the rudder.

The tail followed MiG-19S practice. The fin had symmetric S-11 profile with a thickness/chord ratio of 6 per cent, the leading-edge sweep being 61°. Total area was 3.8sq m (40.9sq ft) including the 0.965sq m (10.4sq ft) rudder, which was operated manually with aerodynamic and mass balances ahead of the three hinges. The slab tailplanes had a leading-edge sweep of 55°, A6A symmetric profile and span of 3.726m (12ft 2⅝in), with antiflutter rods projecting ahead of the square tips. They were mounted outboard of fixed root platforms and set at an anhedral angle of –4°. They were driven by a BU-44 power unit at the base of the fin. The tail control rods were housed in a small spine along the fuselage, and the flight-control system was protected by an ARU-3V artificial-feel unit.

The landing gear closely resembled a lightweight version of that fitted to the I-3 and I-7 family, with pneumatic disc brakes on all three units and hydraulic retraction. The castoring nose unit had a KT-38 wheel carried on a trailing fork and fitted with a 500 × 180mm tyre. It retracted forwards into a narrow box between the inlet ducts closed by two doors. The main legs had KT-27 wheels fitted with 660 × 200mm tyres, and retracted diagonally forwards ahead of the rear spar while the wheel pivoted through 87° to lie almost upright (leaning slightly outwards) in the side of the fuselage outboard of the inlet duct, the bay being closed by a door hinged up by its own actuator.

Under the rear fuselage were two large curved ventral fins, which the OKB called keels, with erosion-resistant steel strips along the bottom. Ahead of these were two perforated door-type airbrakes which hinged down diagonally to 40°, and a third airbrake was driven down to 25° further forwards. On each side of the front airbrake was an NR-30 gun, faired in slim blisters and slightly staggered with the starboard gun further forwards than its partner. The installation was similar to that of the I-7U, with a rectangular steel panel ahead of the muzzle, with a channel to allow the shells to pass. The guns were fed by 60-round belts housed in magazines filling the space between two frames between the air duct and outer skin, loaded through doors on each side of the fixed transparent rear section of canopy. Spent links were stored, but cases were ejected through the underside of the fuselage. Originally it had been intended to fit three guns, but this was considered too much for such a small aircraft.

The main canopy resembled that of the I-7U, comprising a single large Plexiglas moulding with an inserted optically flat windscreen with electrothermal heater elements. This moulding was carried in a magnesium-alloy frame pivoted up by a pneumatic ram near the hinge. The seat was of SK faceblind type, which on being fired carried the rear part of the canopy with it, forming a windbreak to protect the pilot. A hinged arm above the seat adjusted the seat/ canopy link to the height of the pilot.

A total of 1,679 litres (369gal) of fuel could be housed in four tanks made of T6 aluminium around the inlet duct and engine. They were separated by firewalls with flametraps, and nonreturn valves were fitted in the feed pipes. The system was replenished by three gravity fillers beside the spine. There was provision for a streamlined four-finned drop tank of 400 litres (88gal) capacity.

The engine drove pumps for the Main and Utility hydraulic systems, operating at a nominal 211kg/sq cm (3,000lb/sq in). These served the flight controls, airbrakes, flaps, landing gear and nosecone. A single 28V starter-generator charged two Ag/Zn (silver/zinc) batteries. Inverters and transformers provided 115V and 400Hz supplies for the avionics, instrumentation and ice protection. The pneumatic system served wheelbrakes, canopy drive and edge seal, pilot VKK-6 partial-pressure and anti-g suit, gun charging and cocking and emergency landing-gear extension.

Only a single pitot boom was fitted, without airflow angle vanes. It was mounted under the fixed nose, and to avoid damage on the ground the rear attachment could be disconnected and the boom pivoted upwards. Provision was made for the attachment of a pylon under each wing for a bomb or rocket launcher, but these were never fitted. Avionics comprised an RSIU-4 vhf radio in the top of the nose served by the usual sloping mast behind the canopy, an ASP-5N gunsight with SRD-1 *Radal* ranging radar, an ARK-5 radio compass with a flush antenna under the nose and GMK magnetometer causing blisters in each side of the fin, an *Uzel* homing receiver, MRP-48 landing marker receiver, *Sirena* radar warning in the top of the fin, *Bariy*-M IFF, and an AKS-5 combat camera in the upper splitter in the inlet.

An extremely attractive aircraft, finished in polished metal, the Ye-2 was completed very quickly in December 1954. It was taken to the LII airfield where Mosolov began factory testing on 14 February 1955. Considering that it had an interim low-powered engine, he pronounced it to be excellent. Agility was outstanding, one of the few shortcomings being that in yawed flight the slat on the forward-rotated wing tended to slam open, causing severe turbulence and control loss. Testing was left unfinished, because of the interim engine.

Span 8.109m (26ft 7¼in); length 15.37m (50ft 5in), (excluding boom) 13.23m (43ft 4⅞in), (fuselage, from inlet lip) 11.737m (38ft 6in); wing area 21sq m (226sq ft).

Weight empty 3,687kg (8,128lb); internal fuel 1,360kg (2,998lb); weight loaded 5,334kg (11,759lb).

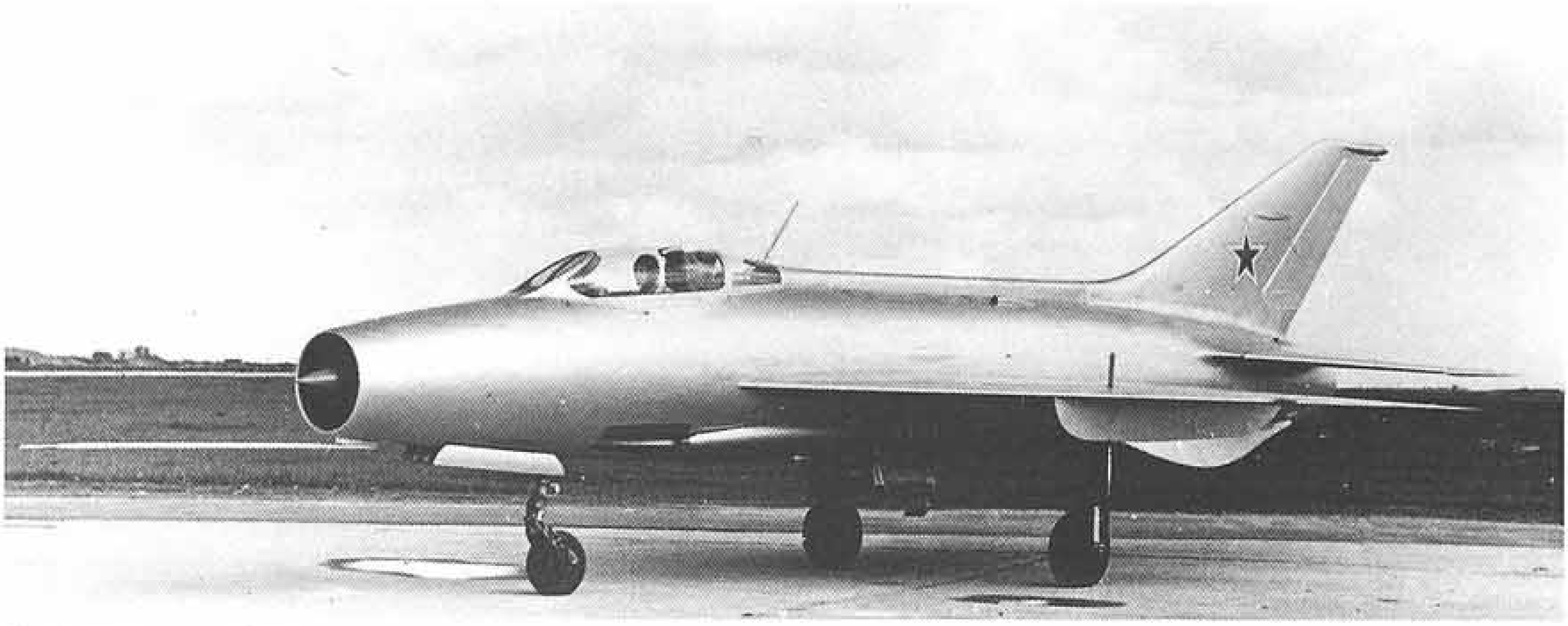
Maximum speed 1,920km/h (1,193mph, Mach 1.8) at 11,000m (36,089ft); service ceiling 19,000m (62,336ft); range (estimated) 1,220km (758 miles); takeoff run 700m (2,297ft); landing speed 250km/h (155mph); landing run 800m (2,625ft).

Ye-4

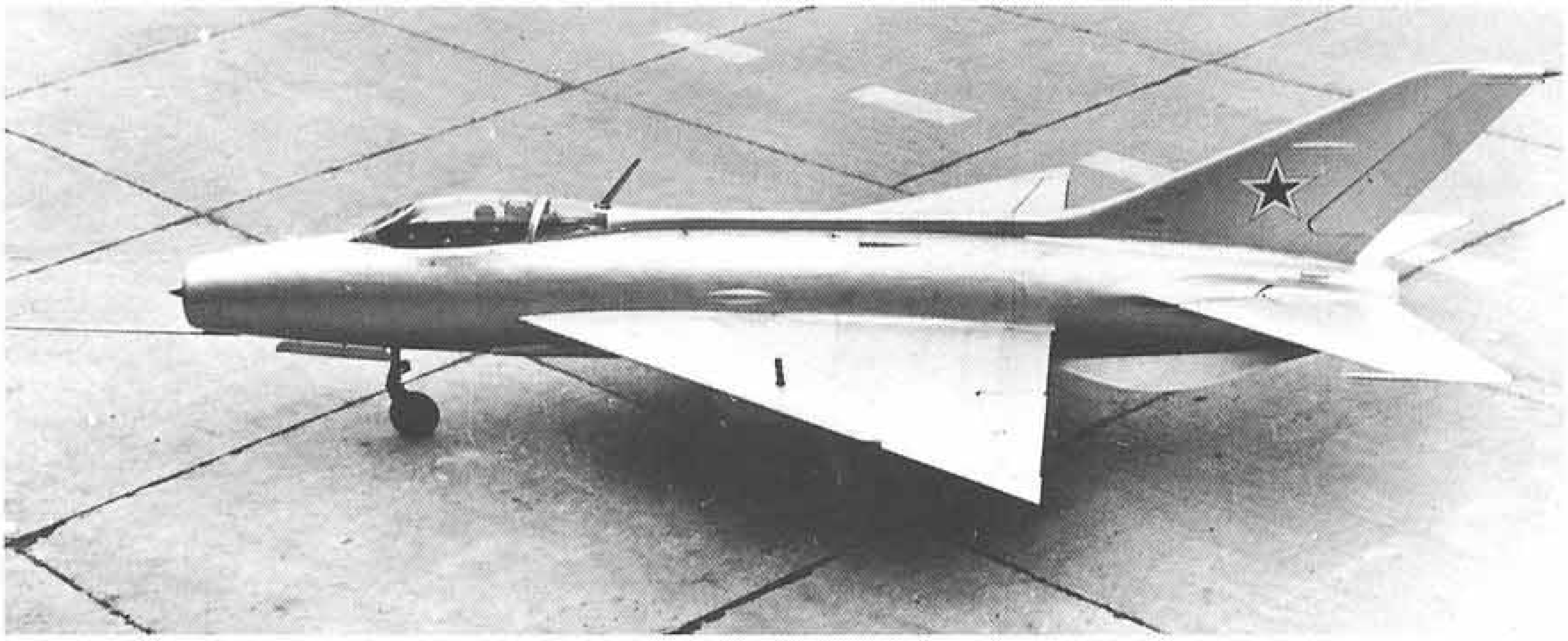
Spurred by the enthusiasm of a senior OKB aerodynamicist, Pyotr Krasilshchikov, and with the close collaboration of CAHI, the OKB decided to build two prototypes with a *balalaika* triangular wing, retaining the horizontal tail to enhance combat manoeuvrability and allow high-lift flaps to be used for landing. The new wing had S-9s profile, with the thickness/chord ratio varying from 4.2 per cent at the broad root (a remarkable figure for the mid-1950s) to 5 per cent near the pointed tip. Leading-edge sweep angle was 57°, and the wings were again set at zero incidence but with the reduced anhedral of –2°.

Structurally, the new wing was totally different from that of the Ye-2. The main spar ran from the root to the tip rib, at the flap/aileron junction there was a strong forged rib aligned parallel with the root, and two spars (called beams by the OKB) were provided at 90° to the root, one terminated by this rib and the other meeting the junction of the rib with the main spar. Ahead of the main spar the ribs were at 90° to the leading edge, which was fixed and had no slats. The trailing edge was at 90° to the fuselage, and this combined with the reduced span to result in the flaps being pure rectangles driven by centrally mounted hydraulic jacks. The ailerons were likewise of shorter span, with even greater taper than before, made in one piece and again driven by a BU-45 power unit. The new wing was nearly 200kg (440lb) lighter than the swept wing.

The fuselage and tail were almost identical to those of the Ye-2, though the much greater wing-root chord resulted in the wing attachments extending right back to Frame 28 (the rear-fuselage joint). Unlike the swept wing, the root rib was not enlarged to form a faired platform extended to front and rear. The changed wing geometry had the effect of moving the hinge point of the main landing-gear legs outwards and to the rear. As the wheel was housed in the same fuselage bay as before this increased track from 2.679m (8ft 9½in) to 2.692m (8ft 10in), and wheelbase from 4.41m (14ft 5⅝in) to 4.48m (14ft 8in). When the main legs were extended an indicator rod projected vertically up above the wing, and because of the movement of the leg pivots the retracted 660 × 200mm tyres caused small blisters in the fuselage skin above and below the wing.



Ye-4 (AM-5 engine). (OKB)

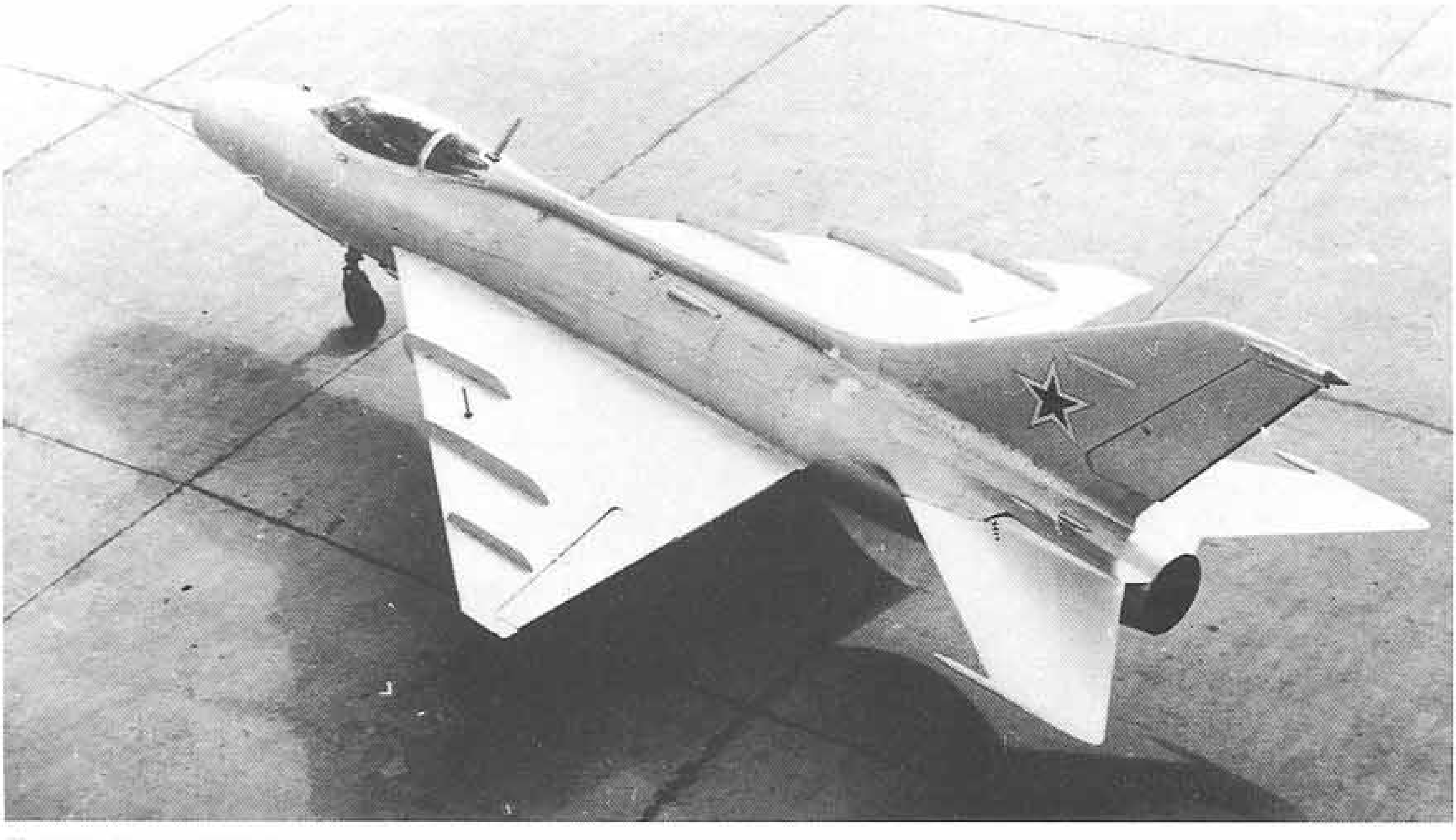


Ye-4 (AM-5 engine). (OKB)

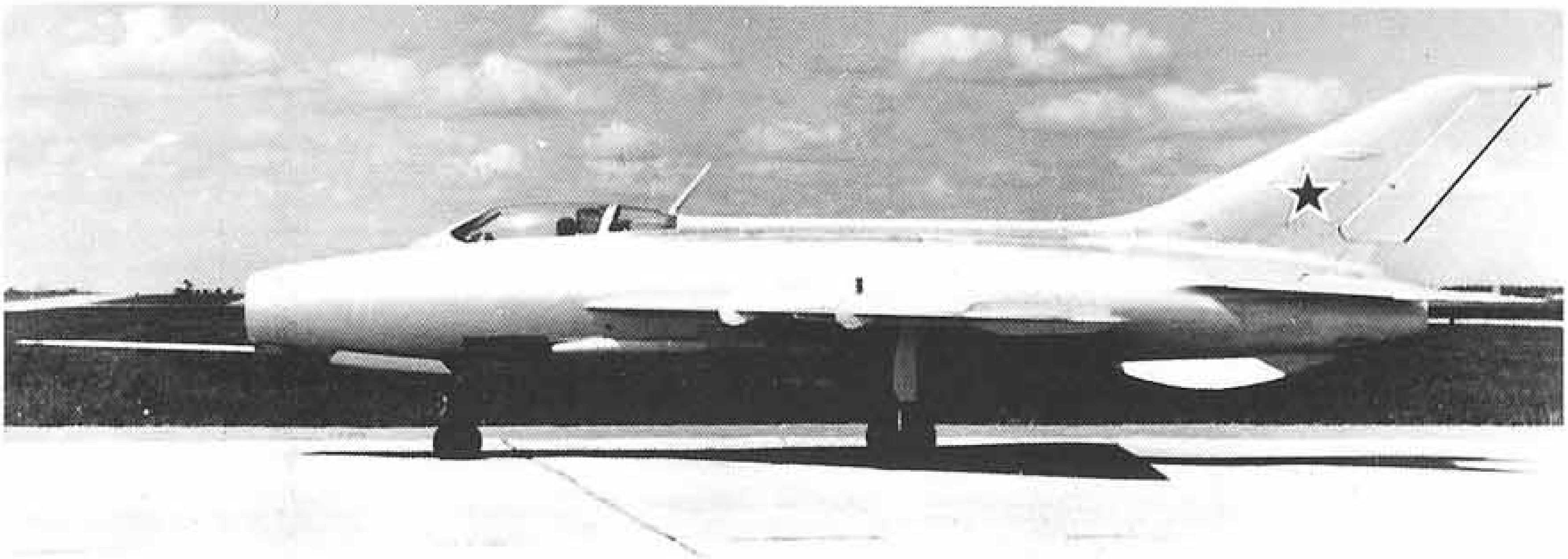
The first *balalaika* (delta) was powered by an RD-9Ye, with the same ratings as that of the Ye-2. Again the tail end of the fuselage was tapered mainly from above and projected well behind the rudder, which was made smaller by replacing its lower part by extra fin area. Around the ducts and engine were four fuel tanks with the smallest capacity of any aircraft of the MiG-21 family, 1,570 litres (345gal), with provision for a 400lit drop tank. Above the starboard side of the nose was added a standby pitot tube. The only other change was to fit a later radar ranger, the *Konus* (cone). This aircraft was designated Ye-4, and because it was repeatedly improved some accounts mistakenly state that two were built.

The pilot assigned to the Ye-4 was Sedov, and he began the factory test programme on 16 June 1955. Again the aircraft was nice to fly, and distinctly more agile than the Ye-2, but maximum speed was extremely disappointing. Instead of the '1,970km/h' which has been widely published, it was only the figure given in the specification. At supersonic speeds the curves of aircraft thrust and drag often run very close together. The point where they cross is the maximum speed attainable, and a small difference to thrust or drag can make a big difference to the speed reached.

Mikoyan drove his aerodynamicists mercilessly to come up with solutions. In July the Ye-4 appeared with a large fence on the underside extending from the leading edge to the fixed rib between the flap and aileron. In August the same aircraft appeared with these fences replaced by three overwing fences. The innermost extended round the leading edge but stopped at the main spar, the middle fence extended round the leading edge and almost to the aileron, and the outer fence started at the leading edge and was shallower than the others, stopping at the aileron.



Ye-4 (RD-9I engine). (OKB)



Ye-4 (RD-9I) with increased-chord rudder. (OKB)

With the three overwing fences the tips were removed (*see* data). Then the outer leading edge was rebuilt to extend chord forwards, with a sharp 'dogtooth' discontinuity at its inner end. In this condition the Ye-4 was handed to the LII research institute of the MAP (Ministry of Aviation Industry) and subjected to tests at high angles of attack, proving that it remained controllable at an angle of attack (AOA) of 25°.

As one route to higher speeds the Ye-4 was re-engined, though not with the AM-11. The new engine was the RD-9I, fractionally more powerful than the RD-9Ye. Sedov first flew the Ye-4 with the RD-9I on 5 September 1956, the day after he flew the second Ye-2A. Because of its disappointing performance the Ye-4 was retired on 20 September 1956.

At the end of 1955 the Ministry of Aviation Industry was so sure that one of the MiG light fighters would be chosen for production that it allocated the Service designation MiG-21 to the delta and MiG-23 to the swept-wing aircraft. The very disappointing performance of the delta suggested that the production aircraft would be the MiG-23, and the first series order for a lightweight MiG was for five (some documents say ten) MiG-23 fighters to be built at Gor'kiy. Later this designation was used for entirely different aircraft.

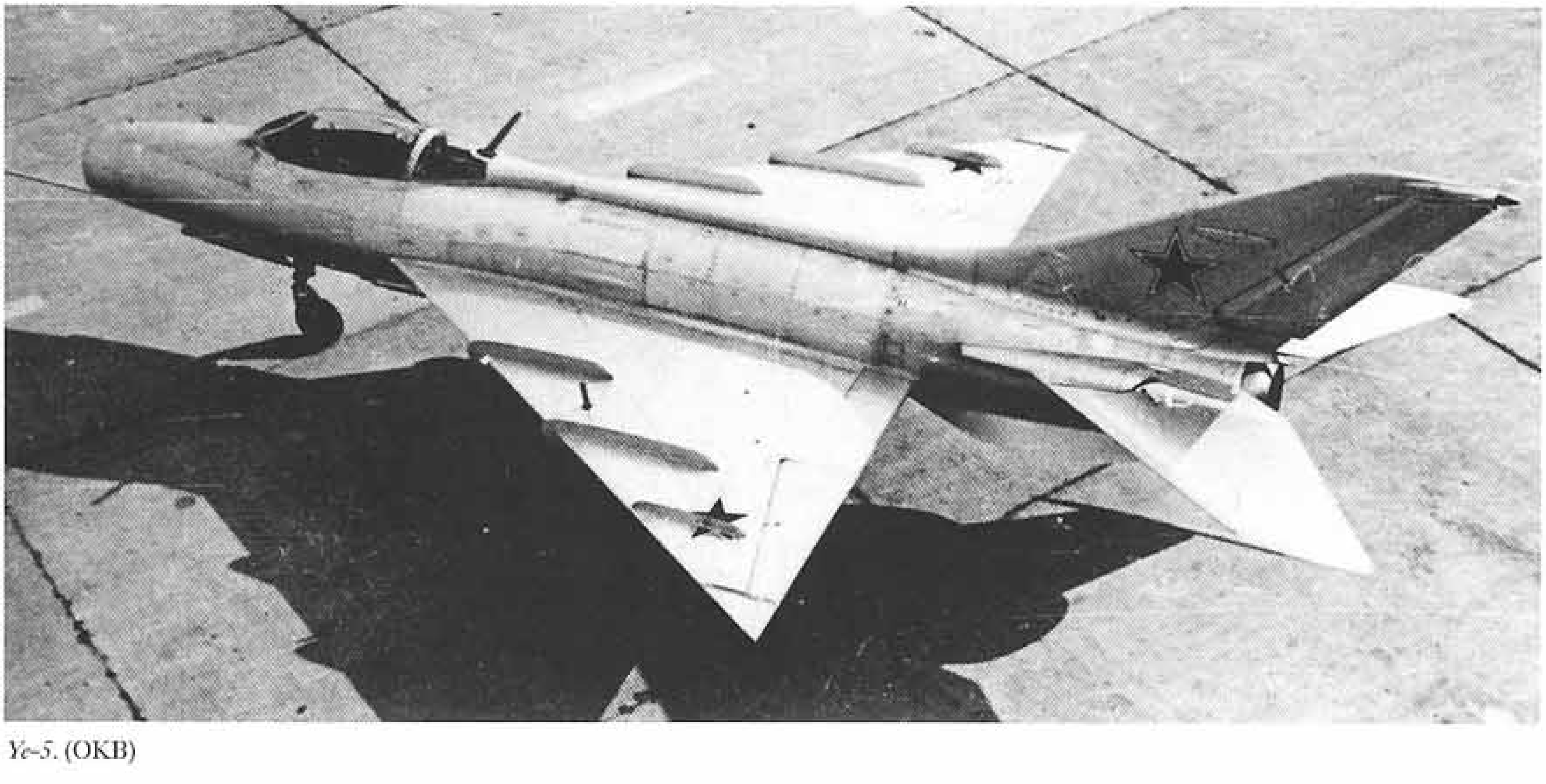
Span (original) 7.749m (25ft 5in), (tips removed) 7.149m (23ft 5½in); lengths as Ye-2; wing area (original) 23.15sq m (249.2sq ft), (tips removed) 23sq m (247.6sq ft).

Weight empty 3,500kg (7,716lb); internal fuel 1,300kg (2,866lb); weight loaded 5,200kg (11,464lb).

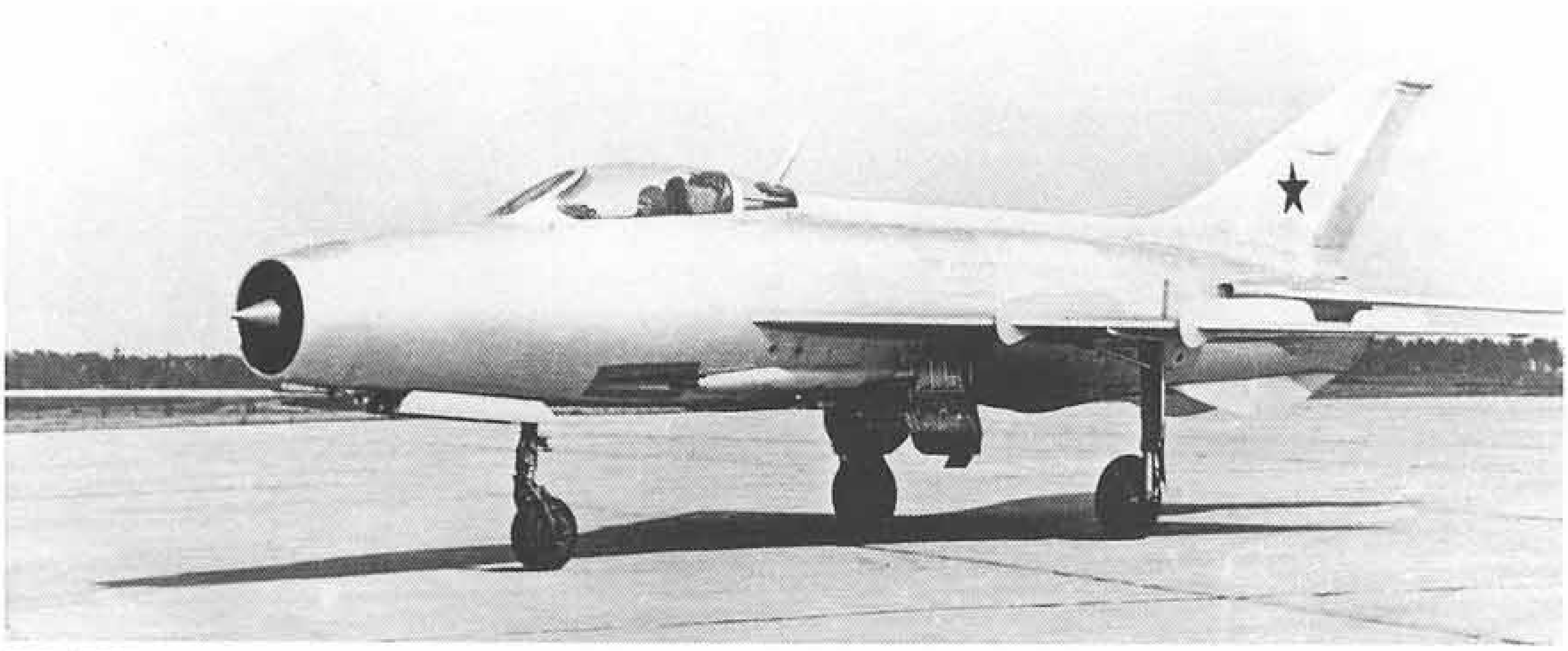
Maximum speed 1,296km/h (805mph, Mach 1.22) at 10,500m (34,448ft); climb to 5,000m (16,404ft) 1.6min; service ceiling 16,400m (53,800ft); range 1,120km (700 miles). No other data.

Ye-5

In September 1955 rival Sukhoi had flown the larger S-1 prototype – roughly equivalent to the I-3/I-7 family but with a better engine and ahead in timing – at 2,000km/h (1,242mph). This posed big problems for Mikoyan, but all he could do was wait for an AM-11 (in 1956 redesignated RD-11) to be received from what had become Tumanskiy's engine bureau. This was again a slim axial-flow turbojet but much more advanced in design than the AM-9. It had two separate rotating assemblies, with three-stage and five-stage compressors each driven by a



Ye-5. (OKB)



Ye-5. (OKB)

single-stage turbine. The first RD-11 received by the MiG team in early November 1955 had dry and afterburning ratings of 3,800kg (8,377lb) and 5,100kg (11,243lb), respectively. Now the MiG light fighters could at last begin to develop.

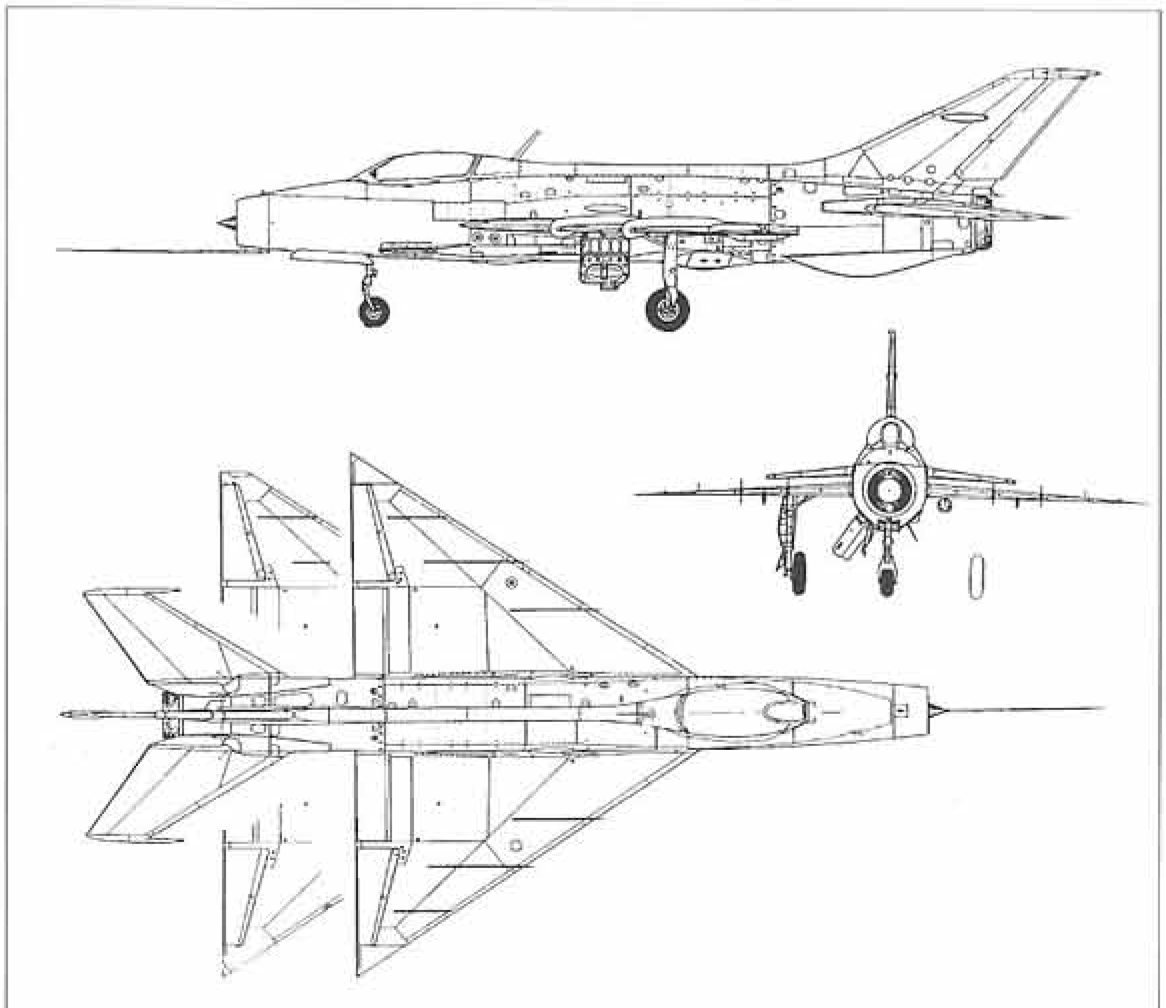
It was decided to install the first RD-11 in the waiting second *balalaika* airframe, the Ye-5. This was fitted with the third form of delta wing with a pointed tip and three overwing fences. Another change was that tailplane span was increased to 3.74m (12ft 3¼in).

The fuselage differed from that of the previous prototypes in that the new engine installation was shorter, with the fuselage cut back to end well in front of the tailplane or fin (though the variable nozzle of the engine, considerably larger than before, projected slightly to line-up approximately with the fin root). Another change was that the fixed tailplane root platforms were extended forwards to reduce the drag of ram inlets for cooling air. Previously the engine and afterburner bays had been cooled only by air induced by main nozzle flow. The control schedule for the nosecone was altered to begin its forward travel at Mach 1.4.

More significant was a complete redesign of the airbrakes. Instead of having one at the front and two at the rear, the arrangement was reversed. A single surface of 0.47sq m (5.06sq ft) was hinged not far ahead of the ventral keels to Frame 25, to which the front wing transverse beam was attached. This brake had a bulged surface with four large perforations, and was driven down to 40°. Under the leading edge, hinged to Frame 11, were two quite narrow airbrakes, each of 0.38sq m (4.09sq ft), driven diagonally out and down to 25°.

The Ye-5 was taken to the test airfield in December 1955. The assigned pilot was Nefyedov, and he began the factory test programme on 9 January 1956. The less-tapered rear fuselage significantly reduced base drag, and this combined with the more powerful engine to give a dramatically wider gap between thrust and drag, adding some 700km/h (435mph) to the level speed attainable.

Nefyedov was delighted with the handling, which he considered superior to the MiG-19, especially at over Mach 1. By far the most serious problem was the immaturity of the engine, which failed repeatedly, on one occasion causing a severe fire and on another a catastrophic break-up of the turbine. During the Ye-5 factory testing ten RD-11 prototypes and one production engine were used, some having been set aside for the swept-wing Ye-2A. In October 1956 the RD-11 was grounded, when the opportunity was taken to extend the nose forwards



Ye-5 (port wing inset, Ye-4/RD-91; starboard, Ye-4/AM-5).

400mm (15¾in) and to fit six fuel tanks from the cockpit to the structural break to increase internal fuel capacity from 1,570 to 1,810 litres (398gal). This extra fuel was still inadequate to meet the required range, because fuel burn of the larger engine was greater than predicted.

Like the Ye-2A, the number of Ye-5 aircraft built is unknown. Either five or ten were made at Tbilisi as 'MiG-21s' in production tooling. In 1957 these were subjected to State trials in competition with either five or ten 'MiG-23s' from Gor'kiy. On 24 June 1956 examples of the Ye-2A, Ye-4 and Ye-5, as well as Sukhoi prototypes, made flypasts in the Aviation Day display at Tushino. This caused confusion in the West. Not a single good photograph was taken of any of these aircraft, and for many years it was believed that the production aircraft were the swept-wing 'MiG-21', called 'Faceplate' and what was thought to be the 'Sukhoi Su-16 Fishbed'. The ventral keels were described as a 'booster rocket'.

Span 7.749m (25ft 5in); length 15.37m (50ft 5in), (excluding boom) 13.23m (43ft 4⅞in), (later) 13.46m (44ft 1⅞in), (fuselage, from inlet lip) 11.33m (37ft 2in), (later) 11.73m (38ft 5¾in); wing area 23.15sq m (249.2sq ft).

Weight empty 4,193kg (9,244lb); internal fuel 1,300kg (2,866lb) as before, later 1,500kg (3,307lb); weight loaded (as built) 5,700kg (12,566lb).

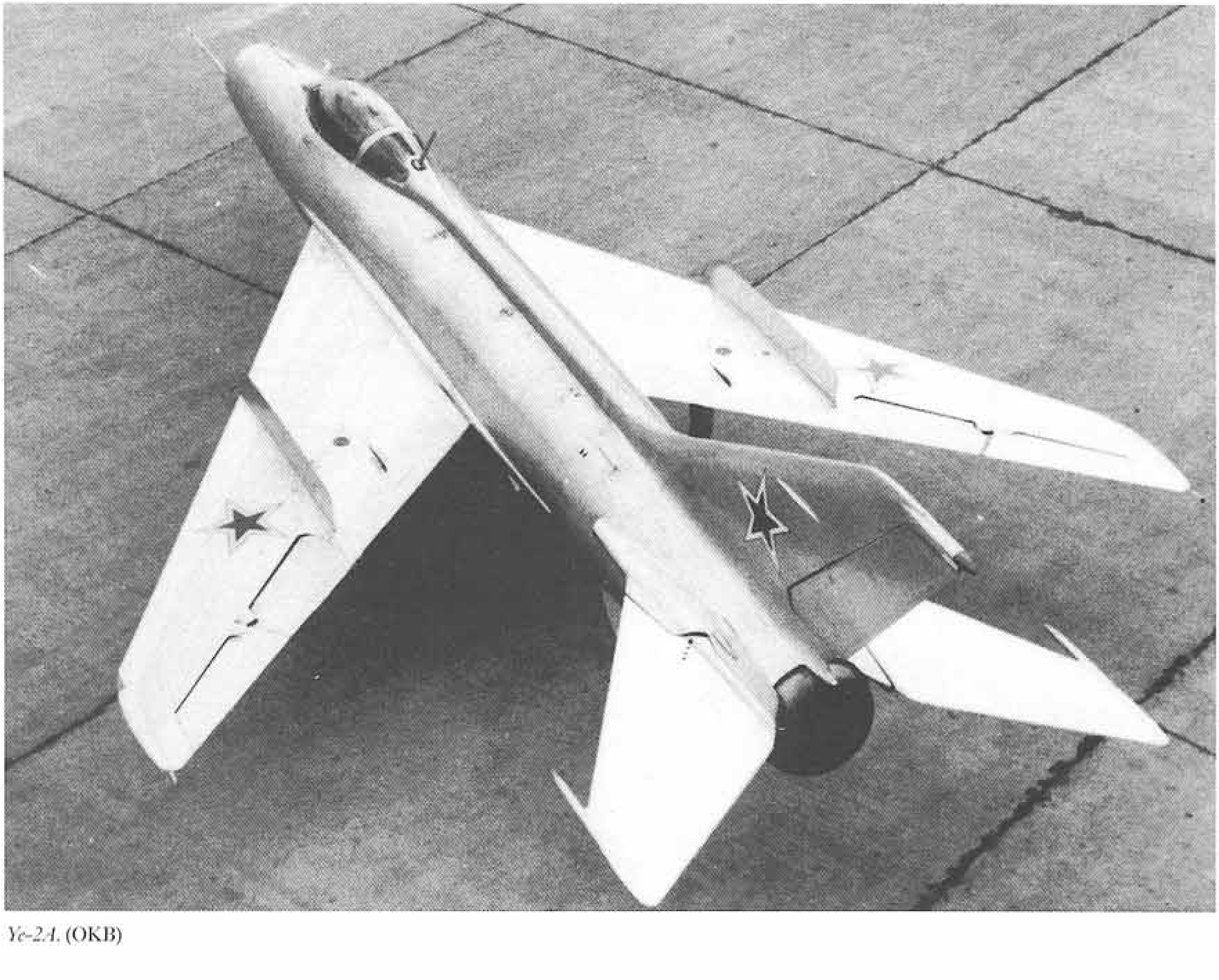
Maximum speed 1,970km/h (1,224mph, Mach 1.85) at 10,500m (34,448ft); climb to 5,000m (16,404ft) 1.6min; service ceiling 17,650m (57,900ft); range (with increased tankage) 1,330km (826 miles); takeoff run 730m (2,395ft); landing speed 280km/h (174mph); landing run 890m (2,920ft).

Ye-2A, 63

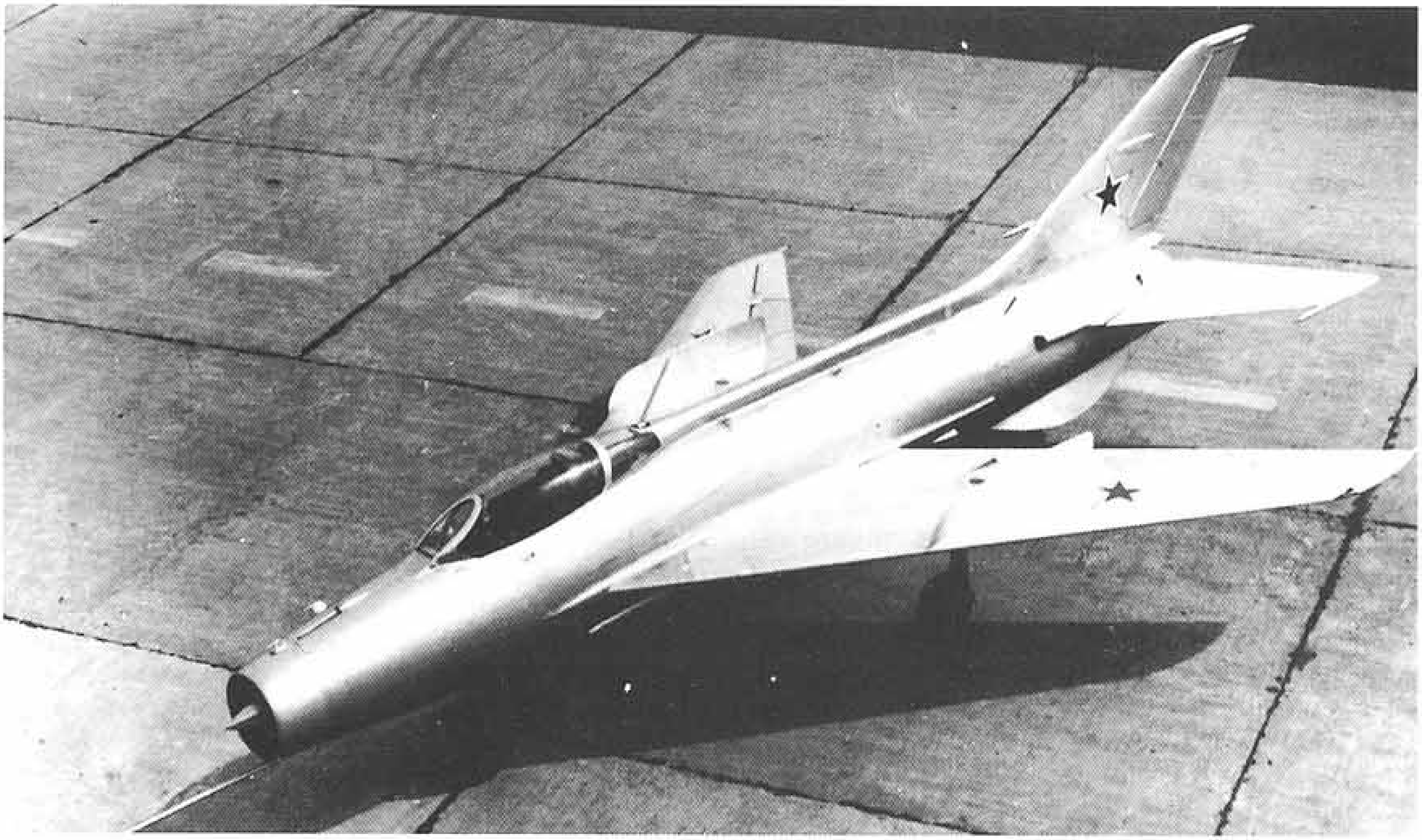
This was the swept-wing counterpart of the Ye-5. The engine was an RD-11, with the Ye-5's rear fuselage and tail and standby pitot above the nose. The wing was similar to that of the Ye-2, but with the slats omitted and large full-chord overwing fences aligned with the flap/aileron junction at mid-semispan. The main fuselage was similar to that of the Ye-2, with the short nose and original arrangement of airbrakes, but with six fuel tanks having almost the capacity of the Ye-5. The landing gear was identical to that of the Ye-2.

OKB-155 built two Ye-2As which, like the other light prototypes, bore no markings except red stars which, as on the deltas, were on the wings and fin only. The first flight was made by Sedov on 17 February 1956. Sedov also began the test programme of the Ye-2A/2 on 4 September 1956. Either five or ten were constructed as 'MiG-23' or *Izdeliye* 63 aircraft at Gor'kiy, completed in 1956. The first of this batch, the Ye-2A/3, was used for power-off landing tests, flown without difficulty by A P Bogorodskiy at the LII. The fourth, Ye-2A/6, was used in prolonged canopy-jettison trials to help perfect the canopy frame and the way it was hinged to the fuselage at the front and, on ejection, to the seat at the rear. The production canopy was developed on this aircraft.

To the astonishment of many, the Ye-2A was not the version selected for production. Points in favour of the delta were lighter structure,



Ye-2A. (OKB)



Ye-2A. (OKB)

reduced turn radius, higher rate of roll and, in general, marginally better supersonic performance. Accordingly, the designation MiG-23 lapsed, to be used again for the next major fighter family. Following its appearance in public the Ye-2A received the ASCC name 'Faceplate'.

Dimensions as Ye-2.

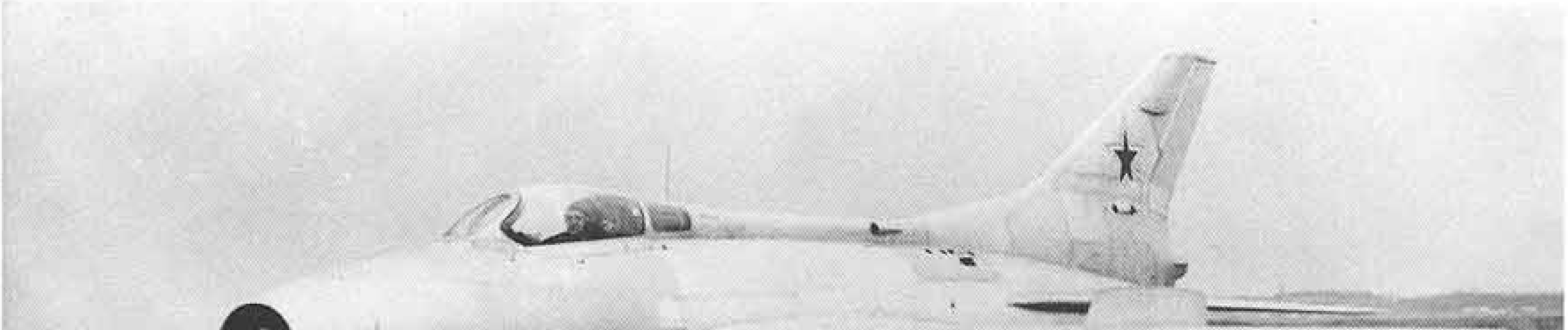
Weight empty 4,340kg (9,568lb); internal fuel 1,450kg (3,197lb); weight loaded 6,250kg (13,779lb).

Maximum speed 1,900km/h (1,181mph, Mach 1.79); climb to 5,000m (16,404ft) 1.5min, to 10,000m (32,808ft) 3.3min; service ceiling 18,000m (59,050ft); range 1,400km (870 miles); takeoff run 680m (2,231ft); landing speed 280km/h (174mph); landing run 900m (2,953ft).

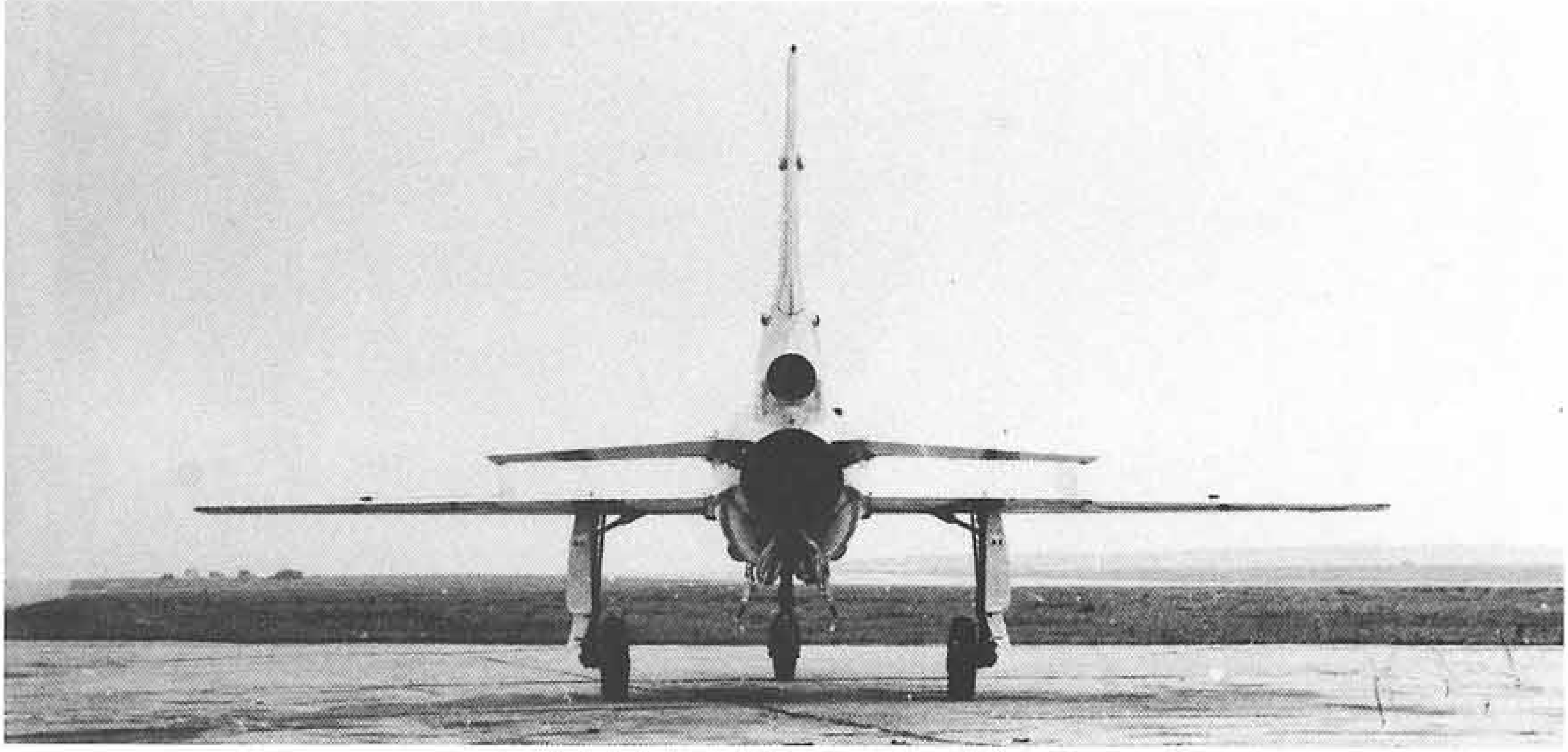
Ye-50 and Ye-50A, MiG-23U, 64

This mixed-power (turbojet plus rocket) interceptor had been designed in 1954 as the Ye-1A. The OKB had rocket experience with the J, or I-270, and was spurred to produce a mixed-power aircraft by the British Saunders-Roe SR.53, and by the knowledge that the AM-11 turbojet would not be available until 1956. The Ye-1A accordingly went ahead with the new designation Ye-50, reflecting its derivation from the later Ye-2A.

Most of the forward fuselage, wings, tailplanes and landing gear were identical to the Ye-2A. The rear fuselage, from Frame 28A, was completely new. In the normal engine bay was an RD-9Ye engine, with maximum dry and afterburning ratings of 2,900kg (6,393lb) and 3,800kg (8,377lb), respectively. This was fed from kerosene tanks around the engine inlet duct. Above the main engine afterburner was the Dushkin



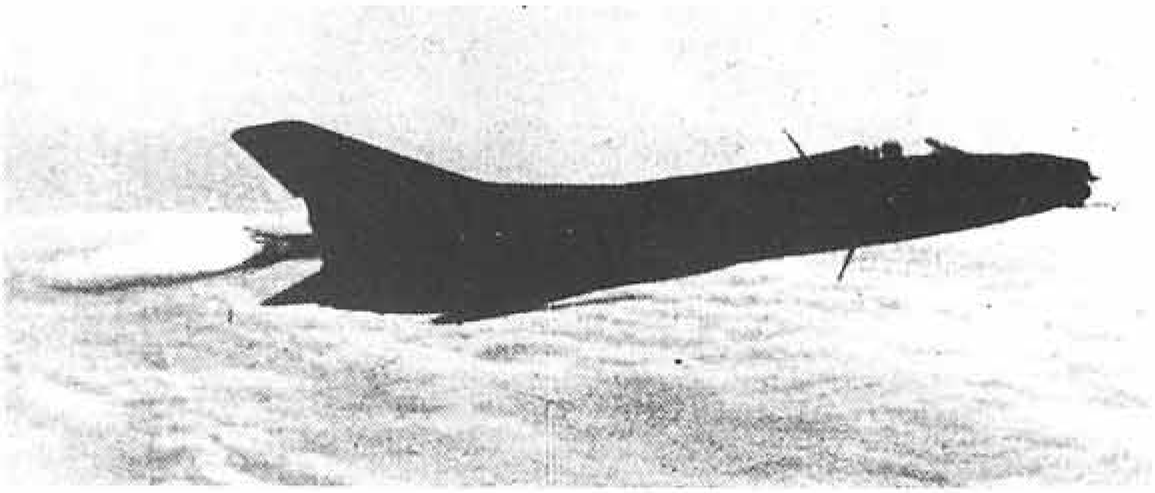
Ye-50/1. (OKB)



Ye-50/1. (OKB)

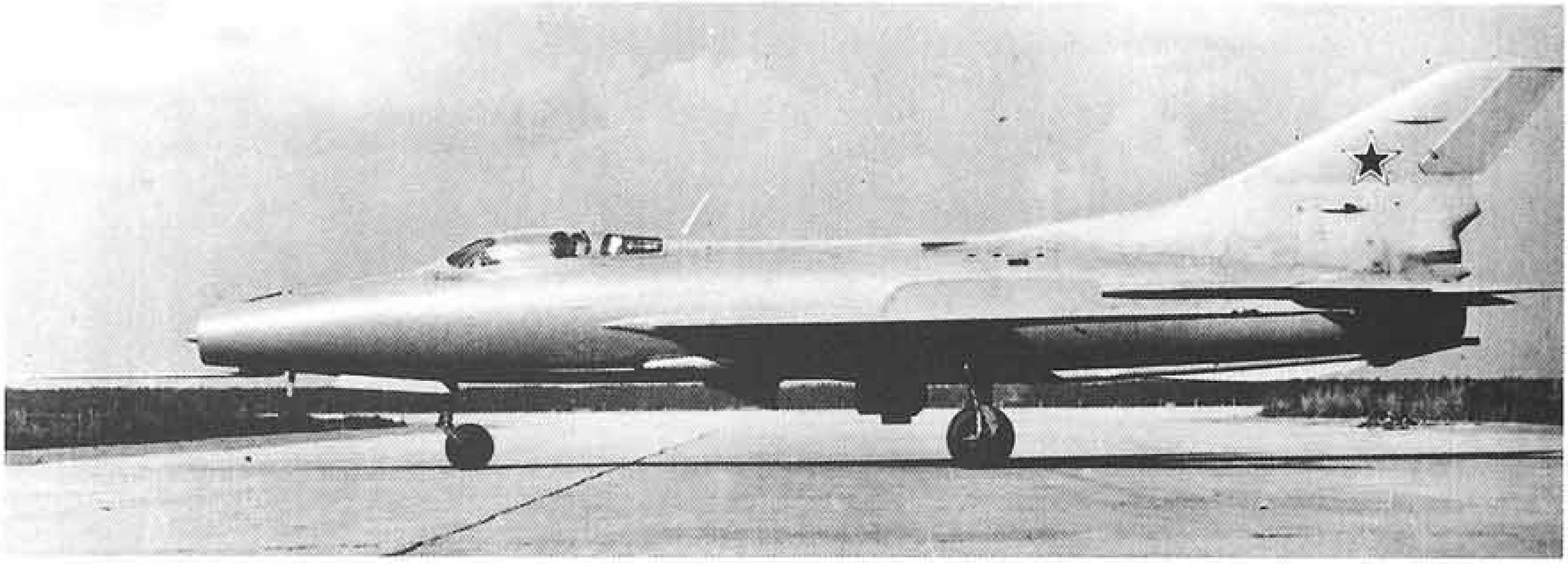
S-155 rocket engine. This was rated at 1,300kg (2,866lb) thrust at sea level, rising to about 1,600kg (3,527lb) at high altitude.

The propellants were RFNA (red fuming nitric acid) and kerosene, fed under high pressure by a turbopump in the greatly enlarged base of the fin driven by high-test hydrogen peroxide Special materials and coatings were needed throughout the rear fuselage because of the corrosive and violently reactive liquids. Stainless steel feed pipes ran in fairings ahead of the tailplane roots. High-pressure nitrogen was used to initiate propellant feed during the starting cycle, purge the entire system after rocket shutdown and, in any emergency, dump the RFNA and HTP overboard. The purging and jettisoning discharged the propellants through separate stainless pipes under the rear fuselage. These replaced the ventral keels, which were rendered unnecessary by the enlarged fin.

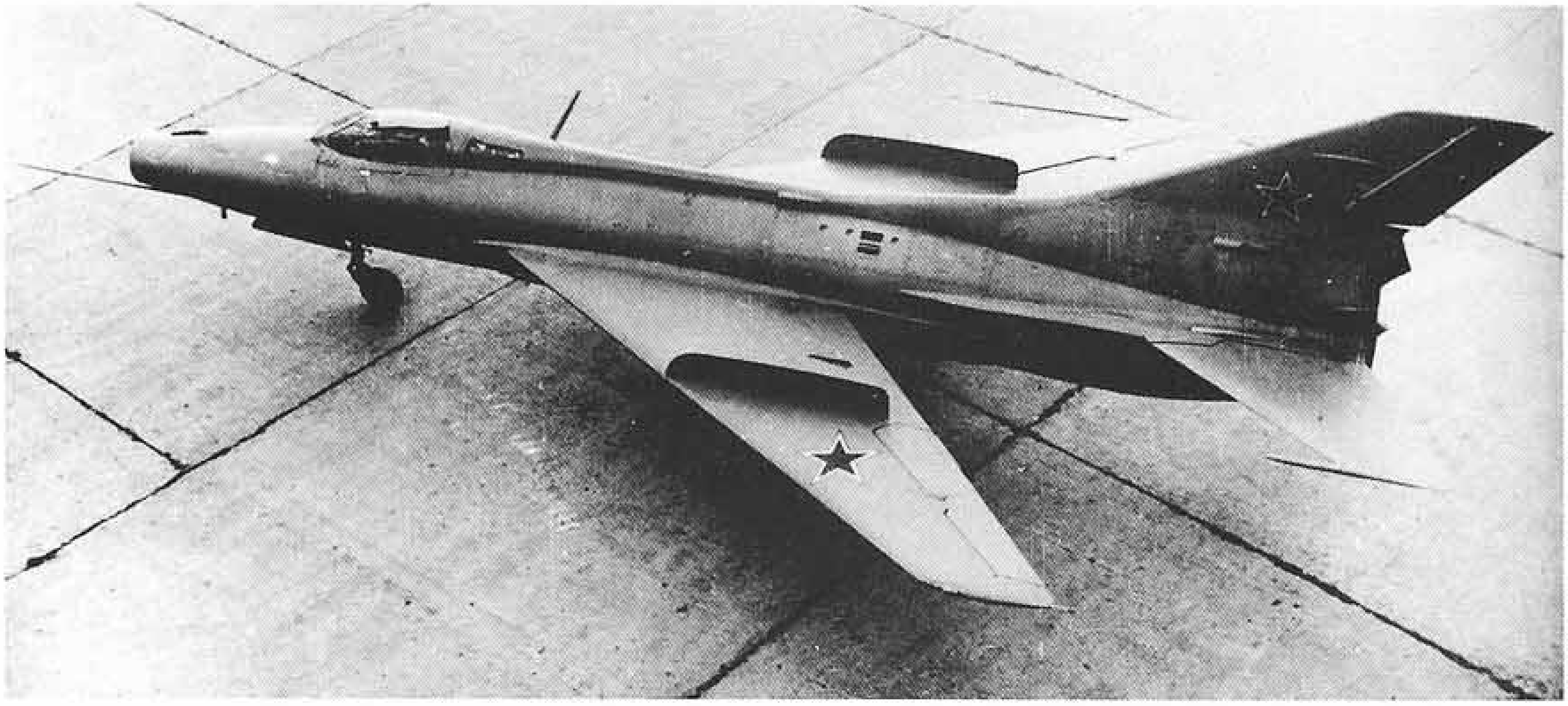


Ye-50/2. (Yefim Gordon archive)

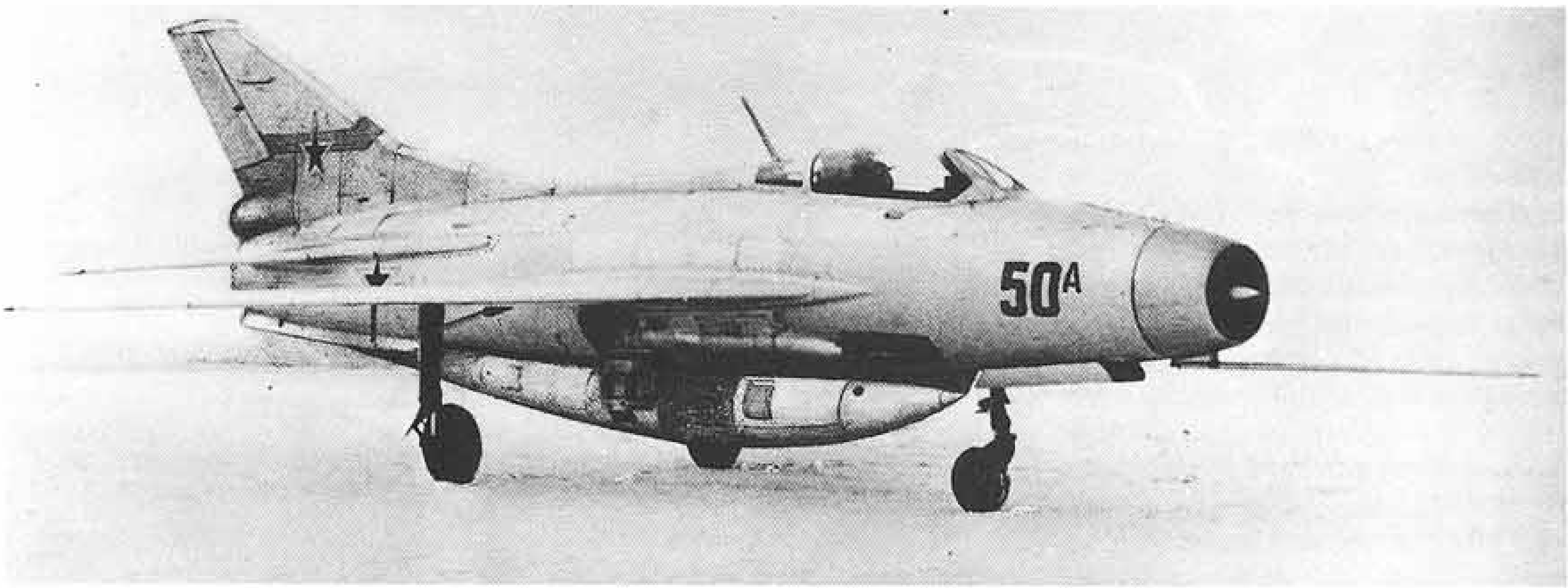
The OKB received contracts for three Ye-50 aircraft, to each of which was assigned a pilot from the LII test centre. The Ye-50/1 was completed in late 1955, a remarkable achievement considering its complexity. Equipment included RSIU-3M, ARK-5 and MRP-48P, but not guns, sight, RWR or



Ye-50/3. (OKB)



Ye-50/3. (OKB)



Artist's impression of Ye-50A. (I Sultanov archive)

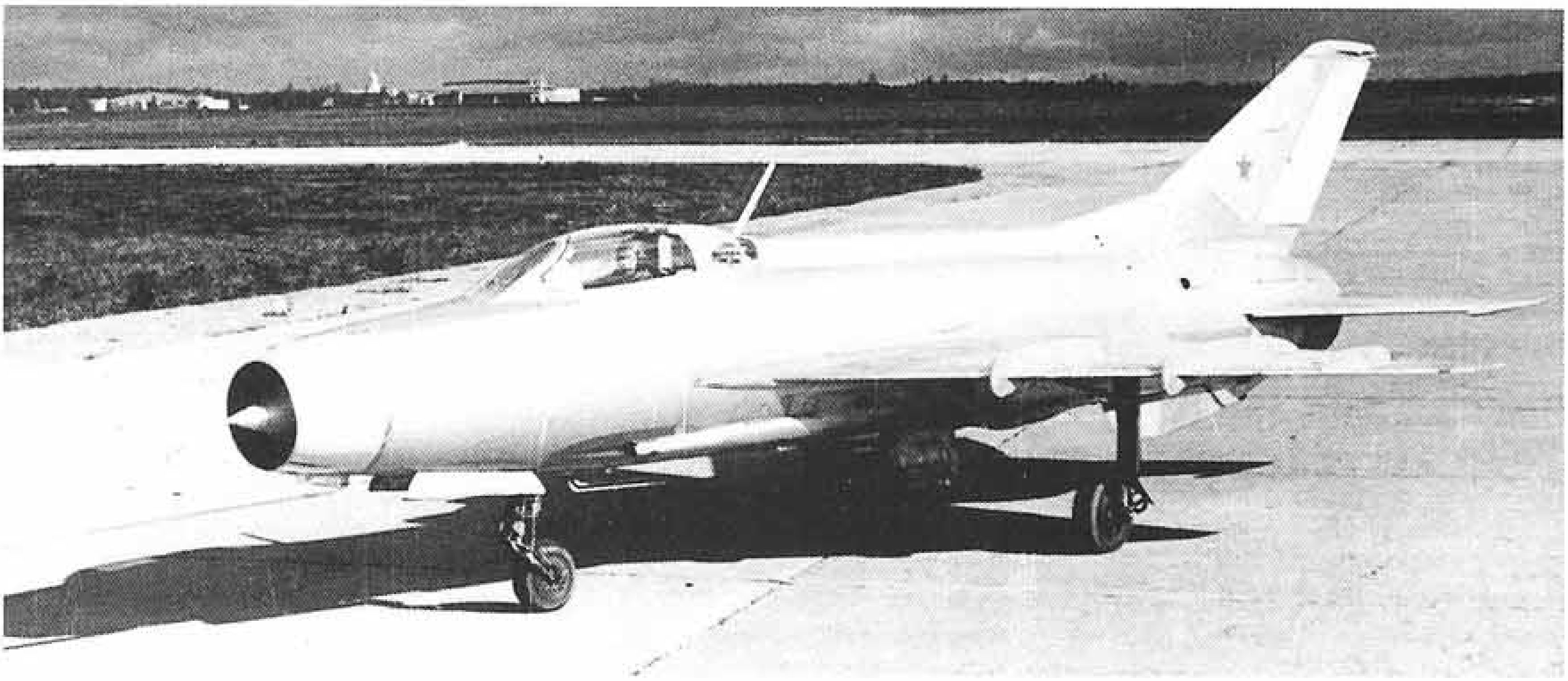
IFF. The assigned pilot was Valentin G Mukhin, who used the turbojet alone on the first flight on 9 January 1956 (the Ye-5 first flew on the same day).

In this condition the Ye-50 was seriously underpowered, and needed almost the full length of the Zhukovskiy runway. Another problem was that, with so much space occupied by rocket propellants, range and endurance were critically short. The rocket engine was first used on 8 June 1956, when it was fired for 11 seconds at 9,000m (29,530ft). On Flight 18 on 14 July 1956 the Ye-50/1 landed short of the runway (probably out of fuel) and was damaged beyond repair.

The Ye-50/2 differed in that, like the Ye-4, the lower part of the rudder was transferred to the fin below. Rudder chord was increased by riveting on a sharp strip along the trailing edge, as the OKB had done with many aircraft. It was also equipped as a fighter, with two NR-30 guns, *Grad* radar ranging sight and *Bariy*-M IFF. It also had a duplicate PVD air-data boom on the starboard wingtip and a duplicate radio antenna under the fuselage. Unlike other MiGs of the 1950s, it was painted overall, in a deep grey.

The pilot of the Ye-50/2 was Valentin P Vasin of the LII. The first-flight date is not recorded, but on 17 June 1957 Vasin climbed to high altitude and then fired the rocket engine to dry tanks. The Ye-50/2 reached the speed given in the data, and a peak altitude of 25,600m (83,990ft), at which level Vasin was in difficulties with his VKK-6 suit. On another flight he fired the rocket during takeoff and climbed to 10,000m in 6.7 minutes and 20,000m in 9.4 minutes (very poor figures, and possibly misprints).

The Ye-50/3 had the nose extended 395mm (15.6in) forwards, in almost exactly the same modification as applied to the Ye-5 and its successors. The nosecone was of the Oswatitsch type, but with only two cone angles, hydraulically translated to a schedule determined by flight Mach number, the system resulting in a small fairing above the nose. One of the fuselage bladder cells was replaced by an integral tank of greater capacity, with the expectation that range would be increased by 200km (124 miles). Among minor modifications was a redesign of the fairing between the rocket thrust chamber and rudder.



Ye-6/1. (OKB)

The pilot assigned to the Ye-50/3 was N A Korovin. On one of his first flights, in autumn 1957, trouble hit: one account says the rocket exploded and another says a fire severed the tail controls. Korovin ejected, but unfortunately the canopy failed to separate from the seat and he was killed.

By 1956 the OKB was studying better ways of building a mixed-power fighter. The answer was to accommodate the additional propellants in a very large tank scabbed on under the fuselage, but conforming to the area rule. After approval of a mock-up of the proposed Ye-50A, the Gor'kiy factory was given a contract for one prototype. Apart from larger mainwheels to handle the greater weight, the whole aircraft forwards of Frame 20 was unchanged. At the rear, two of the seven kerosene tanks were removed, the rocket control system was made more accessible inside the large propellant tank, and two ventral keels were added under the rear fuselage.

When the prototype was nearly complete, Gor'kiy received a contract for two series aircraft. This was expected to be the first of several orders for the production MiG-23U (U for *uskoritel'*, accelerated), which was also given the OKB designation *Izdeliye* 64. At this point the Ministry decided that the future lay not in turbojet-plus-rocket fighters but in more powerful turbojets, and Dushkin's rocket KB was closed, terminating the Ye-50A programme. The data are based on the Ye-50/2.

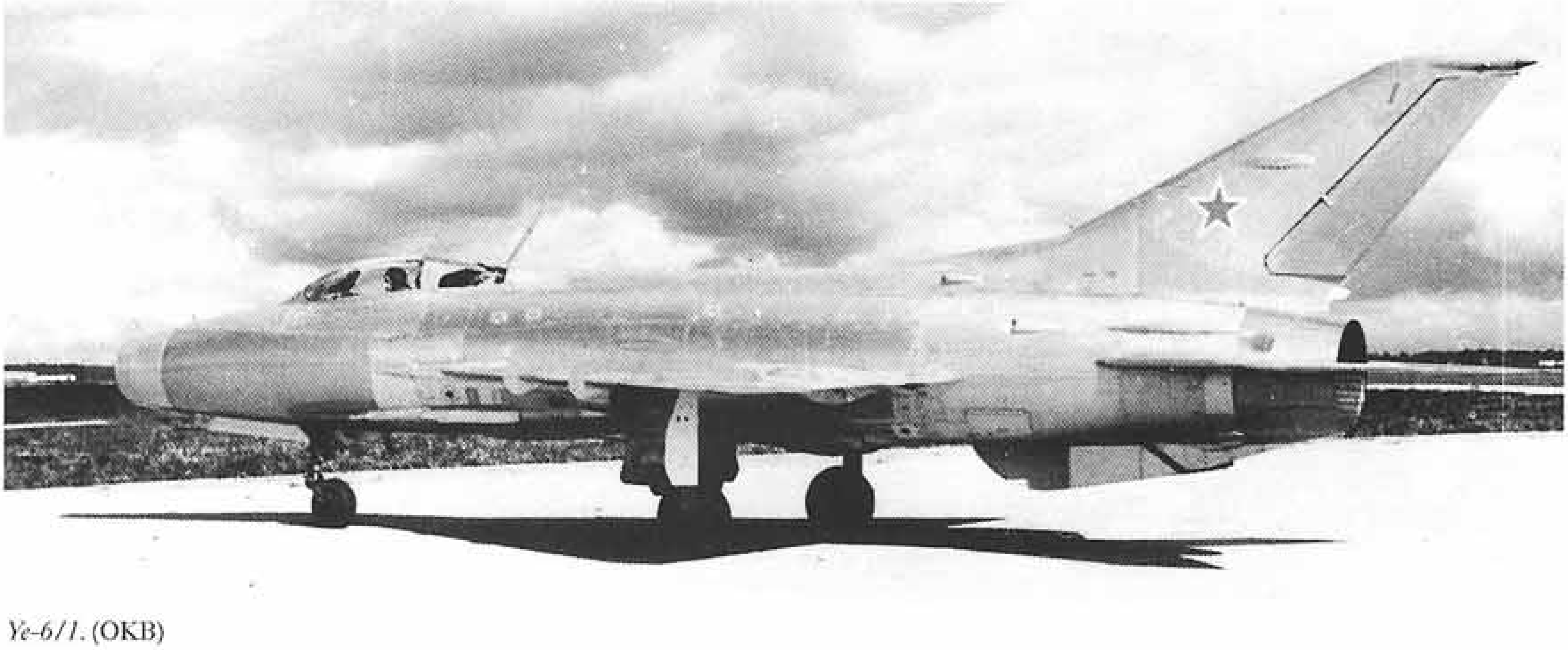
Span 8.109m (26ft 7¼in); length 15.586m (51ft 1⅝in), (excluding PVD) 13.625m (44ft 8½in), (Ye-50/3) 14.02m (46ft), (fuselage of 50/2 from inlet lip) 12.32m (40ft 5in); wing area 21sq m (226sq ft).

Weight empty 4,401kg (9,702lb); fuel and propellants 3,849kg (8,485lb); weight loaded 8,500kg (18,739lb).

Maximum speed 2,460km/h (1,529mph, Mach 2.32) at unstated high altitude; climb, *see* text; service ceiling 23,000m (75,460ft); range 450km (280 miles); takeoff run (both engines) 900m (2,953ft); landing speed (dry tanks) 280km/h (174mph); landing run 860m (2,822ft).

Ye-6

The decision to base the production fighter on the *balalaika* wing was taken in late 1956. By this time Tumanskiy was under intense pressure to improve reliability of the engine, which changed its designation in that year from AM-11 to RD-11 and finally to plain R-11, and which also had the Service designation Type 37. By 1957 Tumanskiy could offer constructors the R-11F-300, or Type 37F, which was not only more mature but also had an improved afterburner. Dry and afterburning ratings were increased to 3,880kg (8,554lb) and 5,740kg (12,654lb), respectively.



Ye-6/1. (OKB)

This was naturally chosen by Mikoyan for the next stage of development, the Ye-6. Under chief engineer I I Rotchik, and systems leader A V Minayev, the Ye-6/1, Ye-6/2 and Ye-6/3 were all built in 1958. Features common to all three were a wing similar to that of the Ye-5 but with tips removed (they contributed little and were a possible hazard to personnel), and the ailerons were reduced in span, stopping well inboard of the squared-off wingtips. The root rib was enlarged as in the swept-wing aircraft to form a faired platform, but this was not continued behind the trailing edge because that was the fuselage break-point.

Though there was little buffet or turbulence around previous tails, the rear fuselage was increased in both diameter and length, which finally gave perfect airflow. The tailplanes were moved to the rear to oversail the new end to the fuselage, and their roots were moved down to the fuselage midlevel whilst keeping the tips approximately in the original place, which reduced the previous anhedral to zero. As the adjacent fuselage was now vertical, the fixed tailplane roots were almost eliminated by extending each tailplane inwards. As the span was unchanged, this made each tailplane larger. The afterburner cooling inlets were left where they were, and so remained isolated above and ahead of the tailplanes. Just downstream were blister fairings for the BU-44 power units, required by the tailplane move.

The vertical tail was slightly increased in area, and joined to the spine by a small dorsal fin incorporating the q-feel inlet. Under the rear fuselage the sloping keels were replaced by a single large underfin on the centreline. The front portion of this fin was a dielectric antenna, beside which on the left side was a thermally insulated box for the 16sq m (173sq ft) circular braking parachute, whose cable was coiled inside the box and emerged to pass beside the underfin to an attachment at the rear. The underfin was shod with a steel skid. The front pair of airbrakes were moved forwards and changed in shape to avoid interference with the lower tailplanes.

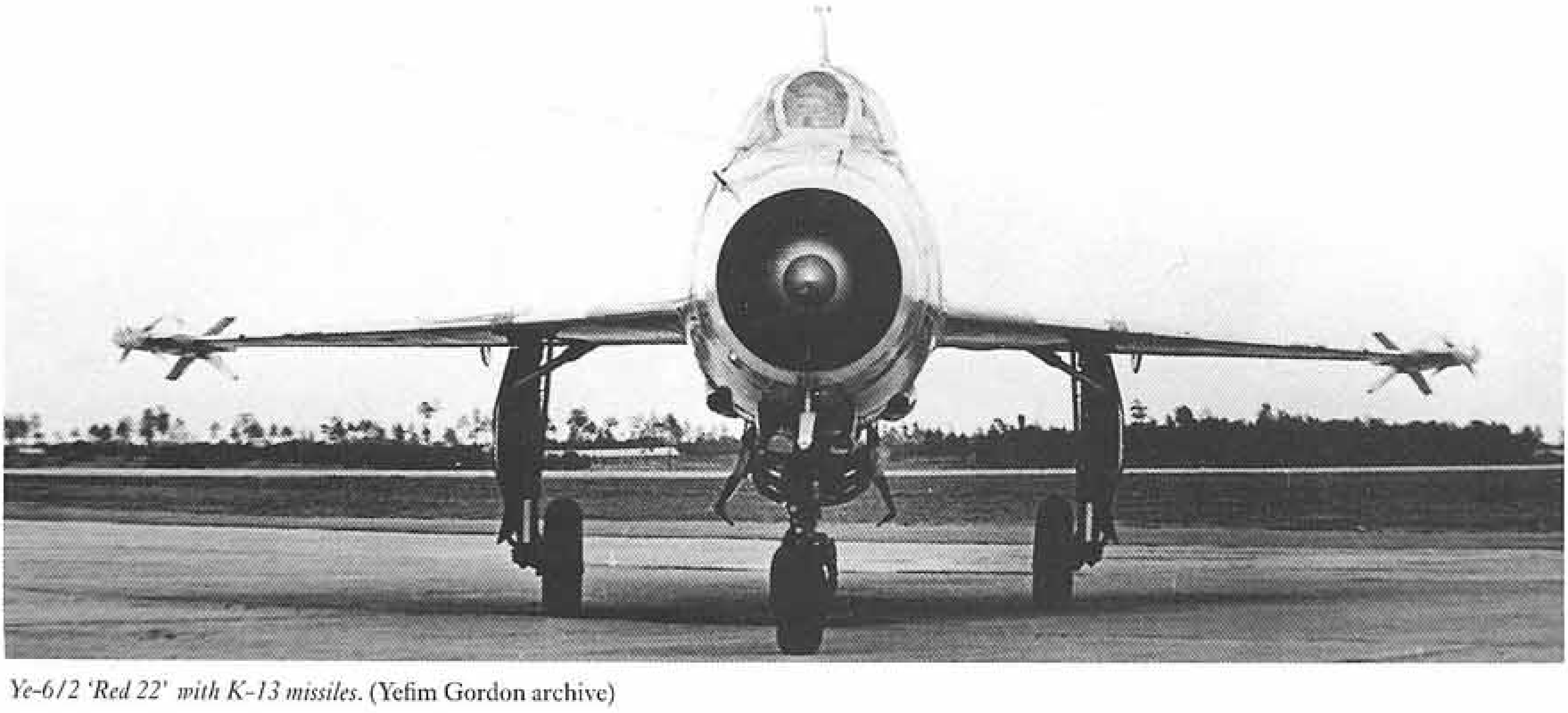
The sharp-edged nose inlet was no longer vertical but slightly inclined to improve pressure recovery at high angles of attack. The central cone was rescheduled to translate forwards at Mach 1.5 and then slide fully forwards at Mach 1.9, at which point the oblique shockwaves would be focused on the lip and the annulus area for the airflow would be only 93 per cent of the maximum. The canopy was similar to the final type flown on the Ye-2A/6, but with the rear part of the frame made even stronger and with the seat-top pickups completely redesigned with two massive external fairings, which were continued over the fixed rear canopy.

Even in the Ye-6/1 almost all the equipment carried was not experimental but production, though a flight-data telemetry transmitter was installed, with a rail antenna behind the nose landing gear. This aircraft was sent to LII Zhukovskiy in May 1958, in which month all the previous *balalaika* and swept-wing prototypes finished an exhaustive aerodynamic test programme. This involved extreme exploration of the design flight envelope, including spinning, the Ye-2 and Ye-2A making 250 flights in this research, the Ye-4 over 100 and the Ye-5 98.

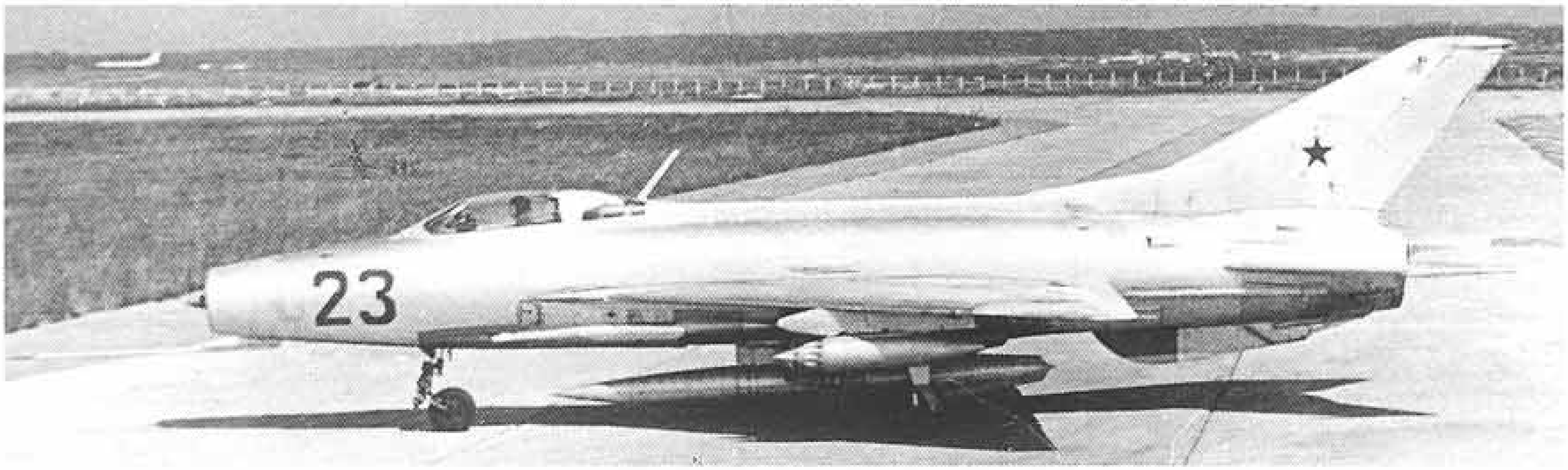
The pilot assigned to the Ye-6 was Nefyedov, and he first flew the Ye-6/1 on 20 May 1958. From the start it proved excellent in all respects, but on Flight 7, on 28 May, the engine flamed out at high altitude and resisted all attempts to restart it. Nefyedov was instructed to eject, but he was determined to save the valuable prototype and its instrumentation. As he neared the runway the falling hydraulic pressure switched in the battery-powered standby hydraulic pump, but too late to avoid total loss of control. Just before touchdown the aircraft rolled inverted, and Nefyedov later died in hospital.

This was a severe blow, and Mikoyan called for answers. A G Brunov proposed improvement of the standby electrically driven hydraulics, but Rostislav A Belyakov, who had recently been appointed Mikoyan's deputy, forcefully argued for a complete duplicated hydraulic system. Mikoyan went along with this, and the Ye-6/2 was completed with a fully redundant hydraulic system, with pressure in hydraulic accumulators maintained by an electric emergency pump.

The Ye-6/2 also introduced a cleaner wing, with the three rather clumsy fences replaced by a single small fence at the location of the outermost of the three, just inboard from the tip of the aileron. Another new feature was an upright rectangular door on



Ye-6/2 'Red 22' with K-13 missiles. (Yefim Gordon archive)



Ye-6/3. (Yefim Gordon archive)

each side of the nose between Frames 3 and 4. These doors were automatically opened inwards very quickly by a hydraulic ram as soon as yaw angle (sideslip) reached a critical value, as sensed by the air-data system. This was intended to avoid compressor stalls, which had been violent enough to break off blades. (In fact, despite these doors, many thousands of subsequent MiG-21s were to suffer from compressor stalls during combat manoeuvres.)

The Ye-6/2 was also the first of the family to have full armament, with two NR-30 guns fed by short 30-round belts (there was room for much more between Frames 13 and 14 outboard of the inlet duct). Under each wing was an attachment for a pylon on which could be hung a UB-16-57 rocket launcher, or an ARS-240 rocket or a bomb up to FAB-500 (1,102lb) size. As before, an attachment under the fuselage was plumbed to take a 490lit (108gal) finned drop tank cleared for flight at up to Mach 1.

The Ye-6/2 was the first aircraft of the new family to be painted with its callsign, 'Red 22'. It was assigned to Konstantin K Kokkinaki, brother of Vladimir K Kokkinaki, chief test pilot for Ilyushin. He began the factory test programme on 15 September 1958. After fifteen flights at Zhukovskiy this aircraft avoided the oncoming winter by being relocated at Krasnovodsk, on the shore of the Caspian Sea opposite Baku. The Ye-6/2 made forty-six flights in the original configuration, needing only four R-11F-300 engines.

The Ye-6/3 was likewise sent to Krasnovodsk, where it was assembled and made its first flight in December 1958. A new feature on this aircraft was yet another pair of auxiliary engine air inlets, in this case almost square in shape and located at Frame 10 immediately below the forward tip of the wing root rib. These were needed simply to admit additional air as the engine came to full power at the start of takeoff. Each had a flush door which was sucked inwards against spring pressure. Other new features were yaw vanes on the PVD nose boom, needed to command the inlet doors on each side of the nose, and the new SRO-2 *Khrom-Nikel* IFF, with triple-rod antennas behind the nose leg and on top of the fin. It bore callsign 'Red 23'. It was the first to take measured figures for range with the centreline tank.

The Ye-6/2 and Ye-6/3 completed factory testing with little further trouble in sixty-one flights. Kokkinaki said they could be flown by 'any normal pilot, not special men'. Up to Mach 2.05 the pilot's manual was devoid of limitations. The Council of Ministers accordingly confirmed their choice of the triangular-wing aircraft, and ordered mass production at former Factory No. 21 at Gor'kiy and also at the former Factory No. 30 in Moscow, called *Znamya Truda* (Banner of Labour), the latter also handling export orders.

In late 1958, while the two surviving Ye-6 prototypes were in intensive test, the OKB was officially told about the Soviet copy of the US Sidewinder missile. This was the K-13, put into production with Service designation R-3S. It needed so little additional equipment in the aircraft that it could easily be adapted to the MiG light fighters, though it was first tested on the modified MiG-19S designated SM-9/3T.

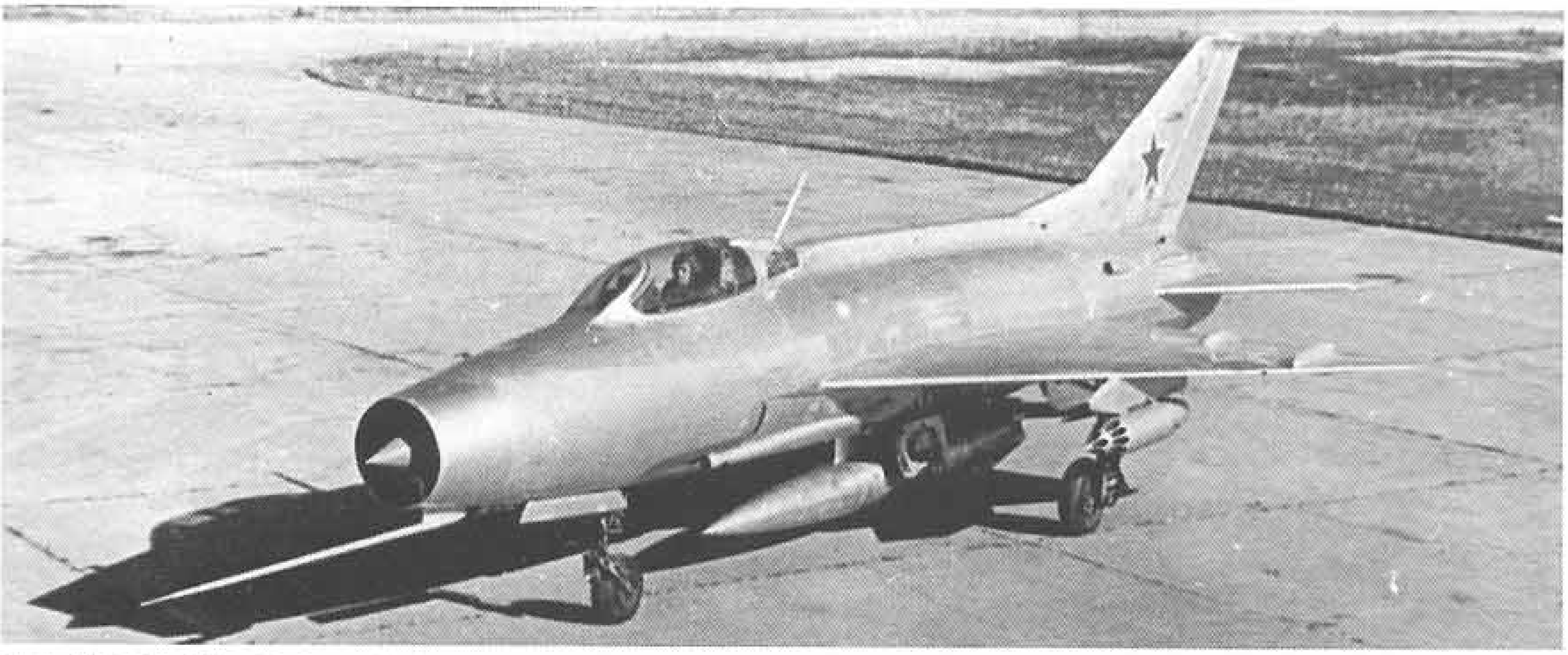
On this aircraft it had been fired from neat underwing pylon interfaces, but, influenced by the good results with the Ye-152/1, to reduce drag the MiG OKB designed a wingtip mounting. After tunnel testing models, the Ye-6/2 was given a new pair of wings with a slight kink in the leading edge in line with the flap/aileron junction. Outboard of this point the leading-edge sweep was reduced to 48°, resulting in a tip chord adequate for the attachment of the necessary APU-13 launcher. The broader outer wing had no fence, and the increased area was expected to result in enhanced manoeuvrability. The modified aircraft resumed flying in September 1960. Unfortunately, when missiles were fired it was found that, like the Ye-152P, the initial missile trajectory was dangerously unpredictable. Accordingly, the MiG-21F went into production with the R-3S carried on the underwing pylons. The Ye-6/2 was the only aircraft of the whole family to have a nondelta wing.

After completion of its factory testing the Ye-6/3 was fitted with a temporarily uprated R-11F-300 engine and used to set world records. On 31 October 1959 Mosolov set a record for absolute speed over a 15/25km course at 2,388km/h (1,483mph), one run being at 2,504km/h (1,556mph, about Mach 2.356). On 16 September 1960 Kokkinaki took the Ye-6/3 round a 100km (62.14mile) circuit at 2,146km/h (1,334mph). Both records were submitted to the FAI as having been set by a fictitious aircraft designated 'Ye-66'.

As noted, though the ASCC called these prototypes 'Fishbed', they were thought to be Sukhoi aircraft. The production MiG-21 was believed to be the swept-wing 'Faceplate', while the MiG-23 was believed to be the Ye-152A. Data essentially as MiG-21F.

MiG-21F, Ye-6T, 72

For some reason there was no production MiG-21; from the outset the designation was MiG-21F (*forsazh*, boosted, which usually meant afterburner, though every prototype had had an afterburning engine). The factory designation was Ye-6T, and the MiG *Izdeliye* (product) number was 72.



Series MiG-21F. (Yefim Gordon archive)

The only series batch of MiG-21F fighters comprised thirty delivered from Gor'kiy in the last four months of 1959 followed by sixty-nine in the first half of 1960. They were almost identical to the final standard of Ye-6/3, and individual aircraft in the batch differed only in the dielectric area at the front of the underfin. Like most fighters, this initial version was the lightest of all MiG-21s, and also had the lowest drag, longest specific range (distance flown per unit mass of fuel), greatest agility, simplest maintenance and lowest price. Subsequent versions, in striving to be more effective, especially at night or in bad weather, were heavier, more complex and much more expensive.

The third series aircraft, Ye-6T/3, was set aside to be fitted with canard foreplanes. These were not powered, but were freely mounted on axes skewed at 40° to align themselves with the local airflow. Each had a leading edge swept at 45°, square tips and antiflutter rods projecting ahead at midspan. Their purpose was merely to reduce static longitudinal stability, but results were judged disappointing.

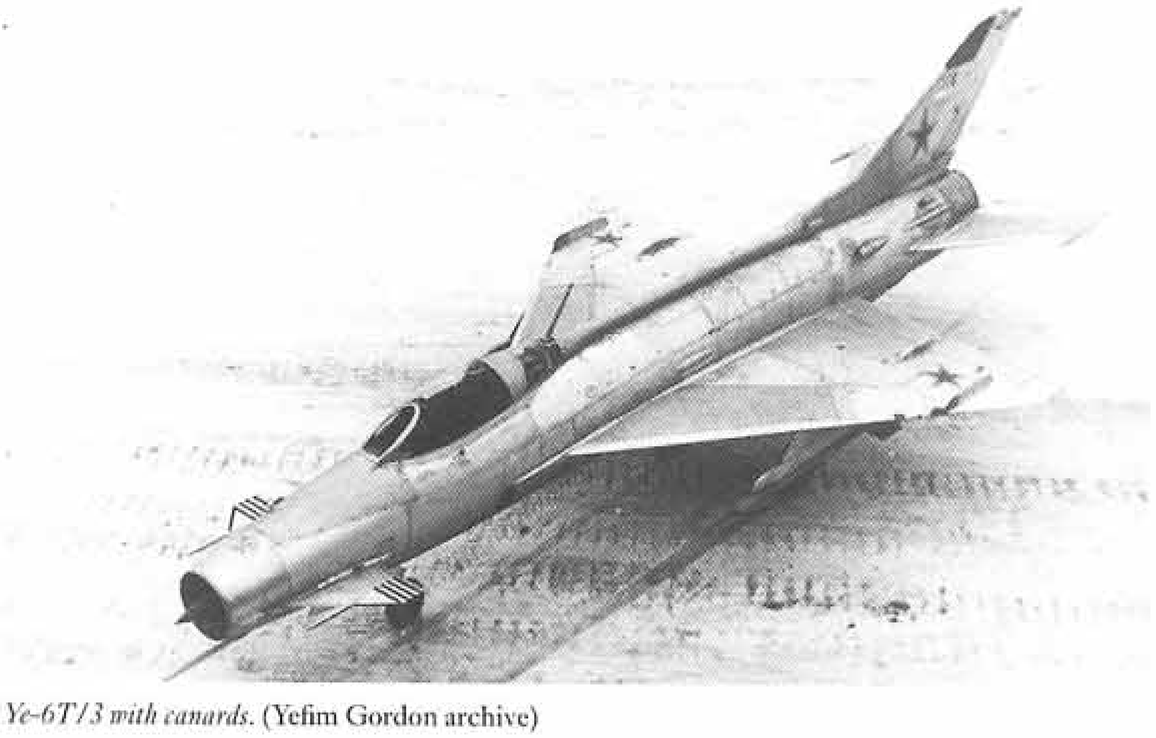
The MiG-21F was a simple aircraft, with two guns, no radar and no autopilot. The ailerons were driven ±20° by BU-45 or B4-45 power units signalled by rods along the leading edge, the *stabilizators* were driven by a single BU-44 over the range +7°/–16.5° (at high speeds these limits were reduced by the ARU-3V artificial-feel system) and the rudder was operated manually by rods inside the spine.

The landing gear was as described previously, with track of 2.692m (106in) and wheelbase of 4.806m (189.2in). Tyre pressures were usually 10.4kg/sq cm (148lb/sq in) in the main tyres and 7.73kg/sq cm (110lb/sq in) in the nose tyre. The mainwheels had pneumatic disc brakes, and the nosewheel was freely castoring and had a pneumatic drum-type brake, all three brakes having antiskid control.

The engine drove separate pumps energizing the General and Booster hydraulic systems to 211kg/sq cm (3,000lb/sq in). The General system served the landing gear, flaps, airbrakes, nosecone, auxiliary inlet doors, afterburner nozzle, autobrakes to stop wheel rotation after takeoff, one chamber of the tailplane BU-44 and the standby (backup) supply to the aileron BU-45. The Booster system served the other chamber of the BU-44 and the normal supply to the BU-45.

The engine also drove a GSR-ST-1200VT-21, which when fed with ground power served as the main engine starter. The engine was supplied during the starting cycle with petrol from a small tank, and at high altitude could also be supplied with bottled gaseous oxygen to ensure light up. When driven by the engine this d.c. machine charged the two 15STs-45A silver/zinc batteries. Two transformers provided 115V single-phase a.c., and two more provided three-phase at 36V at 400Hz. These supplies served the electrothermal windscreen, landing lights hinged down from under the wings, armament controls and all lighting, instruments and avionics.

The fuel system comprised six protected flexible cells in the fuselage with capacities of 235, 720, 265, 200, 240 and 240 litres (51.7, 158.4, 58.3, 44, 52.8 and 52.8gal), plus two inte-



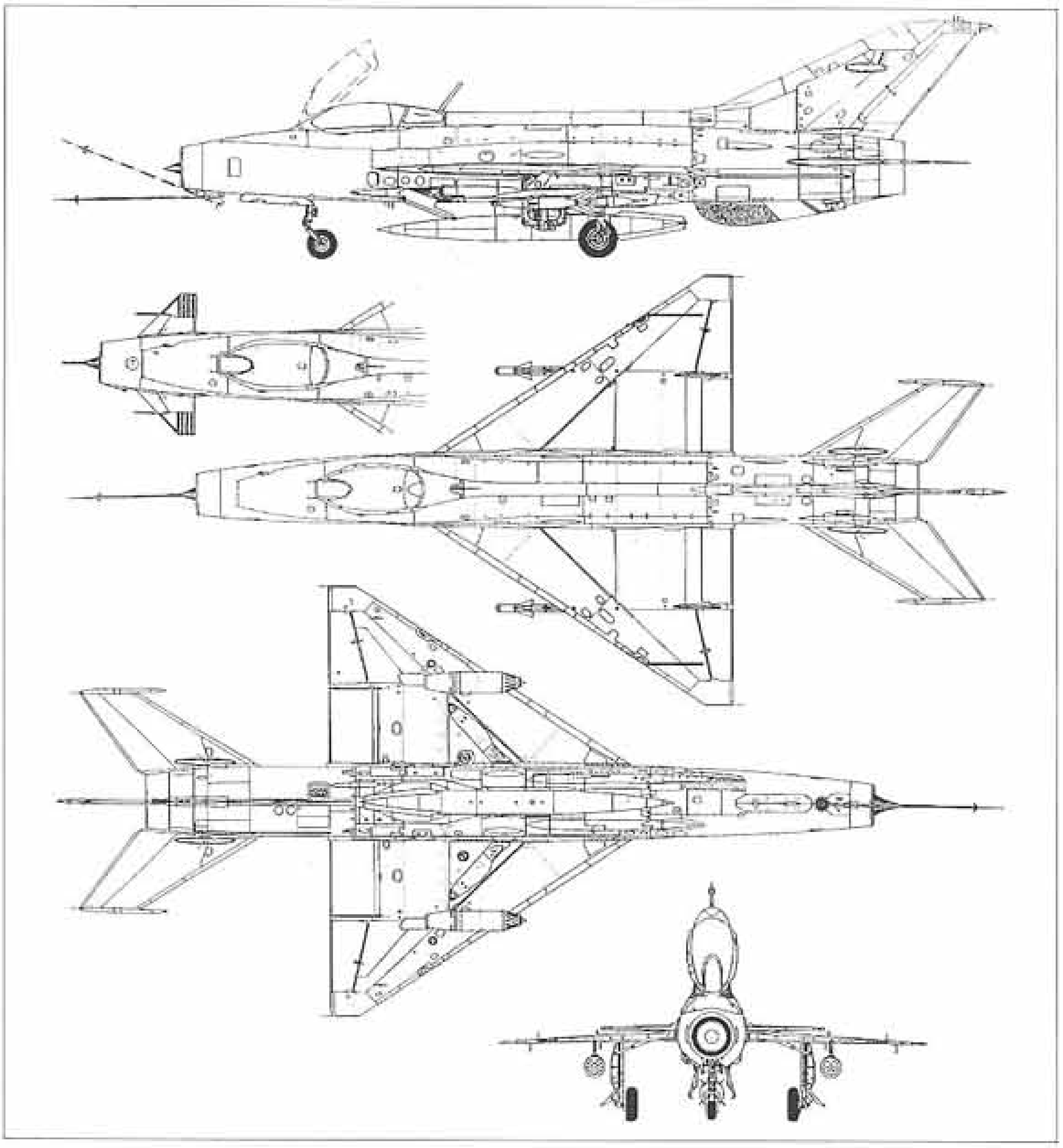
Ye-6T/3 with canards. (Yefim Gordon archive) gral tanks in the rear part of the inboard wings each with a capacity of 190 litres (41.8gal), giving a total capacity of 2,280 litres (501.5gal). There was provision for a cruciform-finned aluminium-alloy drop tank with a capacity of 490 litres (108gal), usable to Mach 1. The engine fire-protection system comprised the IS-2MS warning subsystem, with thermocouples next to the engine-bay cooling inlets and sensing rings around the bay, and methyl-bromide bottles in the bottom of the bay on the starboard side. The KKO-5 pilot oxygen system was fed from six bottles in the wing root serving the VKK-2 or VKK-6 partial-pressure anti-g suit and GSh-6 hermetically sealed helmet.

The designation MiG-21F applied to the first ninety-nine series aircraft only. The ASCC called this type 'Fishbed-B'.

Span 7.154m (23ft 5⅝in); length 15.58m (51ft 1⅜in), (excluding PVD boom) 13.46m (44ft 1⅞in), (fuselage, from inlet lip) 12.177m (39ft 11⅜ in); wing area 23sq m (247.6sq ft).

Weight empty 4,819kg (10,624lb); internal fuel 1,790kg (3,946lb); weight loaded 6,850kg (15,101lb).

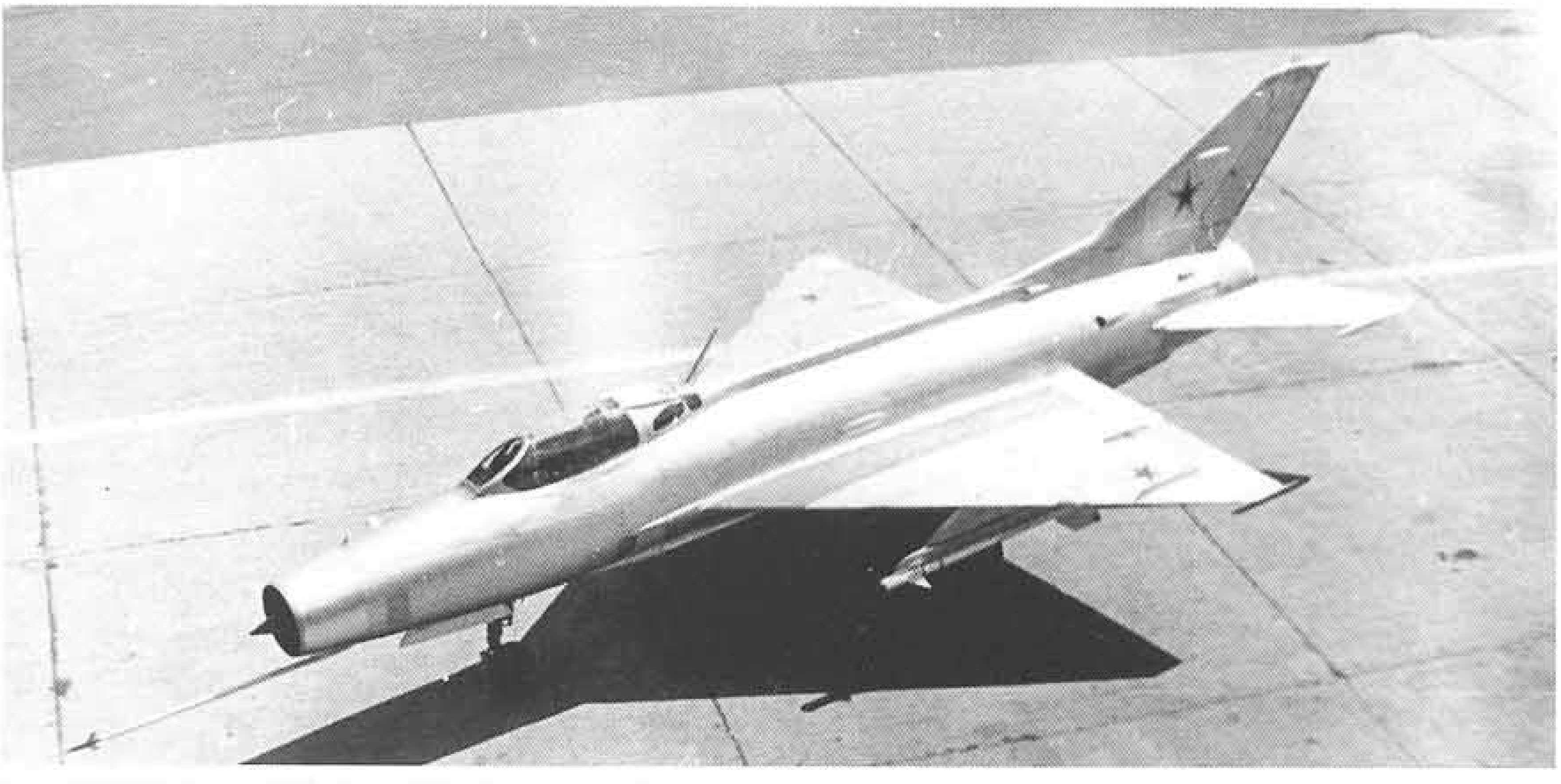
Maximum speed 1,100km/h (683.5mph, Mach 0.9) at sea level, 2,175km/h (1,352mph, Mach 2.04) at 12,500m (41,010ft); climb to 5,000m (16,404ft) 2 min, to 10,000 m (32,808ft) 4.1 min, to 18,500m (60,696ft) 7.5 min; service ceiling 19,000m (62,340ft); range (clean) 1,520km (945 miles); takeoff run 900m (2,953ft); landing speed 280km/h (174mph); landing run (with drag chute) 800m (2,625ft).



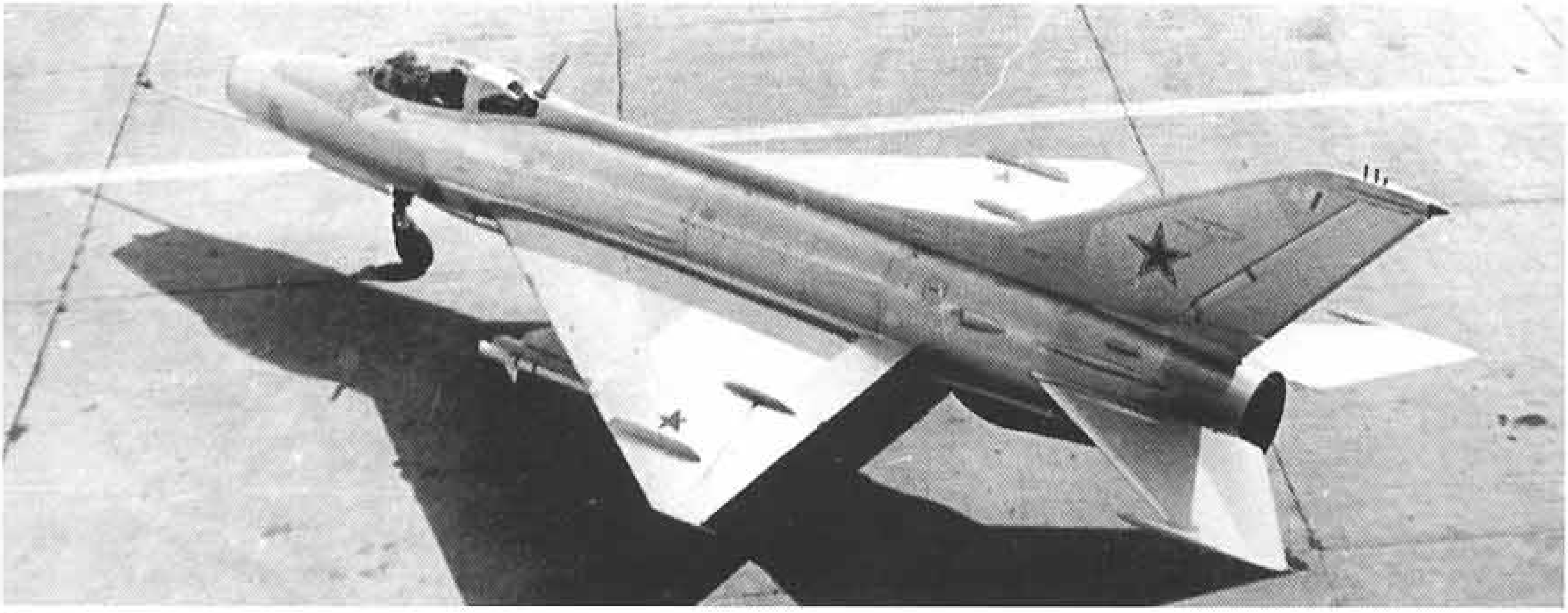
MiG-21F-13 (inset, Ye-6T/3).

MiG-21F-13, 74

As noted, there was a brief halt in deliveries when the Gor'kiy factory had delivered 99 MiG-21Fs. When production resumed there were small differences which resulted in this new designation. The most important modification was the addition of underwing pylons with APU-13 interfaces for the newly introduced K-13 (R-3S) missile. To minimize the growth in weight the left gun and magazine were removed.



Series MiG-21F-13 with K-13 missiles. (Yefim Gordon archive)



Series MiG-21F-13 with K-13 missiles. (Yefim Gordon archive)

A second significant change was to extend the chord of the fin forwards to give a sharp vee leading edge, increasing area of the vertical tail to 4.08sq m (43sq ft). This improved yaw stability, but still did not eliminate mild snaking which often resulted in compressor stalls and surges. Another modification was to fit a specially designed single-axis autopilot, designated KAP-2. This controlled the ailerons only, to provide damping and lateral stabilization in the absence of external cues. If bank angle exceeded 35° it disconnected.

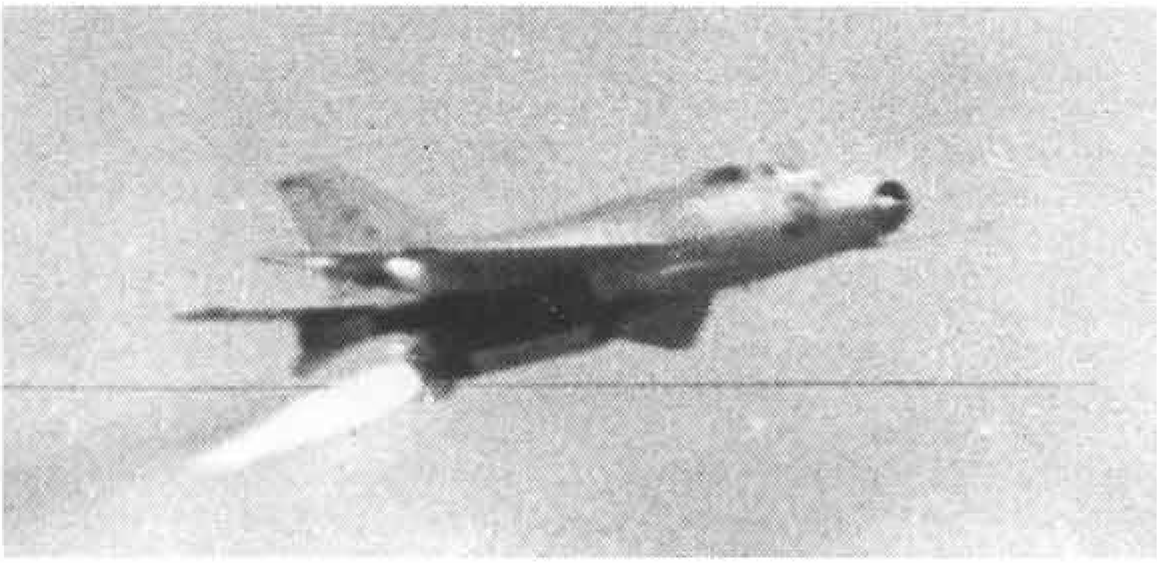
At the sixteenth MiG-21F-13 (the 115th series aircraft from Gor'kiy) the fuel capacity was increased to what at the time was thought to be the limit by adding the planned forward wing integral tanks filling the space ahead of the main spar. This increased internal capacity to 2,550 litres (560gal). As an overload, the centreline pylon was equipped to take a drop tank with a flattened-oval section with a capacity of 800 litres (175gal).

Less obvious changes were to match the new missiles with the SRD-5M *Kvant* (quantum) radar-ranging gunsight, and to provide for an optional AFA-39 reconnaissance camera mounted vertically under the cockpit floor. In the second half of 1960 production at Gor'kiy was 132, followed by 272 in 1961 and 202 in early 1962, when production switched to the MiG-21PF.

These aircraft were received by Frontal Aviation regiments with enthusiasm. Nobody minded the light armament, because the aircraft handled beautifully and was considered able to dogfight higher and faster than any other aircraft in the world. Combined with its low price it could hardly fail to find foreign customers, and the *Znamya Truda* factory produced MiG-21F-13 aircraft for China, Cuba, Czechoslovakia, Egypt, Finland, the German Democratic Republic, Hungary, India, Indonesia, Iraq and Poland.

In 1963–66 the Aero Vodochody factory in Czechoslovakia produced under licence 194 aircraft designated S-106. These differed in small respects from the MiG-21F-13, the only external modification being that the fairing behind the canopy was entirely metal instead of being Plexiglas. This was considered to make little difference to field of view. In 1961 licences for the aircraft and its engine were sold to China. Chinese versions are described later. The ASCC name remained 'Fishbed-B'.

Hungarian MiG-21F-13s. (Yefim Gordon archive)



Ye-6T/1 modified, Ye-66A. (Yefim Gordon archive)

Dimensions as MiG-21F.

Weight empty 4,871 kg (10,739 lb); internal fuel 2,115 kg (4,663 lb); weight loaded 6,915 kg (15,245 lb); maximum takeoff weight 8,625 kg (19,015 lb).

Performance similar to MiG-21F except range with 800lit tank about 1,970 km (1,224 miles).

Ye-66A

In 1960 the Ye-6T/1, the first true series prototype with callsign 'Red 31', was rebuilt into what for record purposes was called the Ye-66A. Whilst retaining the telemetry rail under the rear fuselage, it was given a new fin leading edge which extended chord even further than on the MiG-21F-13, to give a total vertical-tail area of 4.44sq m (47.7sq ft). An additional 170 litres (37.4gal) of fuel was added in the top of the fuselage behind the cockpit between Frames 14 and 17. The canopy was thus faired into an enlarged spine over the new tank, which curved down to rejoin the original spine near the midpoint of the aircraft, where the radio mast was located. This was the first of a succession of larger spines which, whilst trying to adhere to the aerodynamic area rule, enabled fuel capacity to be increased.

Without modifying the inlet and duct, the engine was replaced by an R-11F2-300, with dry and afterburning ratings of 3,950kg (8,710lb) and 6,120kg (13,492lb), respectively. Under the fuselage, on a shallow but very long pylon secured to Frames 16 and 28, was attached a large streamlined package designated U-21, from *uskoritel'*. It contained a Dushkin S-3/20M5A rocket engine, with its nozzle inclined 8° downwards, together with its turbopumps, control system and tanks for nitric acid and HTP. This added about 3,000kg (6,614lb) of thrust at sea level, rising to 3,700kg (8,150lb) at high altitude. The underfin was replaced by two short but extremely deep inclined ventral fins. On 28 April 1961 this aircraft, still 'Red 31', was flown by Mosolov on a zoom climb to a new world record for absolute altitude of 34,714m (113,891ft).

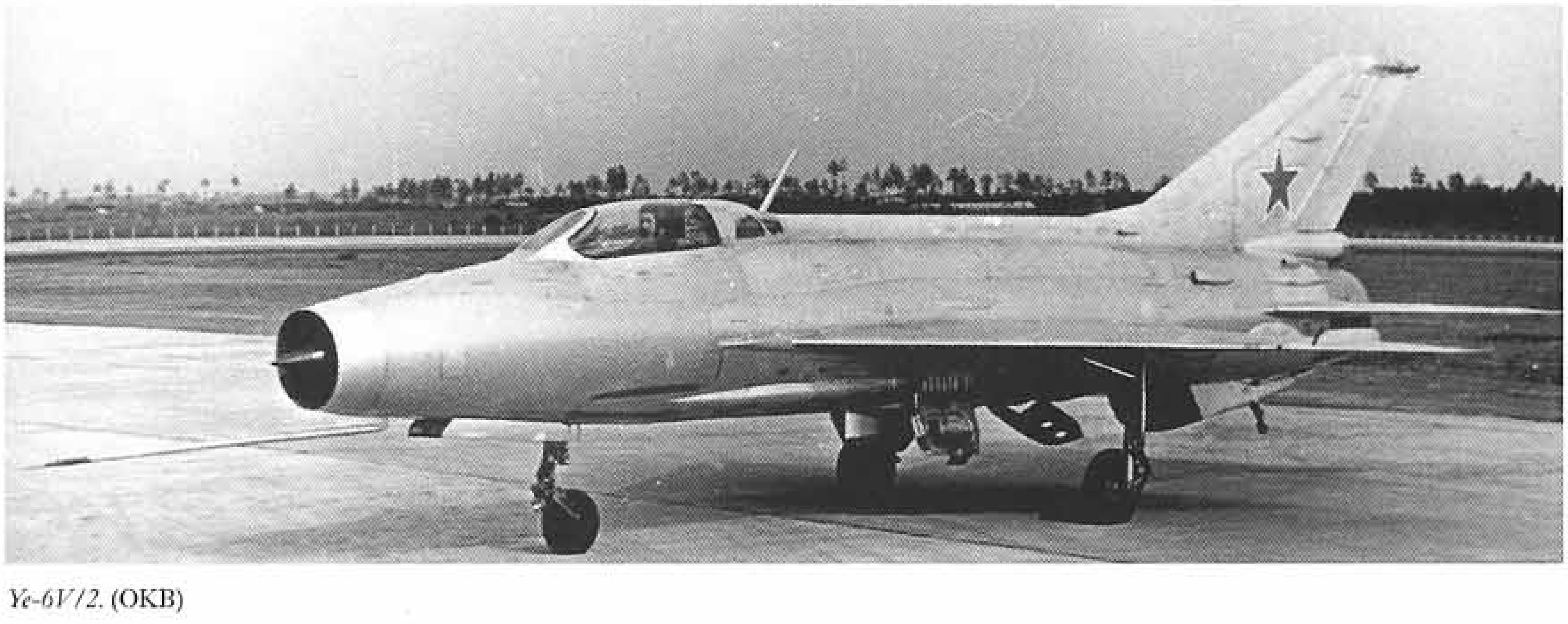
Ye-6V

In 1960 the OKB modified two Type 74 aircraft to explore to what extent aircraft of the MiG-21 family could operate from short unpaved airstrips. Designated Ye-6V/1 and Ye-6V/2, they were both fitted with attachments for two assisted-takeoff solid rocket motors on the lower sides of the rear fuselage. The most important type was the SU-1500, rated at 3,500kg (7,716lb) thrust for 10 seconds, mounted horizontally but with the nozzle inclined to thrust in a line through the centre of gravity of the aircraft. Other rockets were themselves inclined.

A completely new braking parachute installation was fitted, with the canopy housed in a horizontal tube between the rear fuselage and the rudder, replacing a fixed section of fin. Both aircraft also extensively tested wheel/ski landing gear. At a large public airshow on 9 July 1961 Fedotov made a remarkable rocket-boosted takeoff in the Ye-6V/2. It was not until this occasion that Western intelligence agencies finally comprehended that the chosen light fighter was a delta called the MiG-21.

MiG-21P, Ye-7

From the outset it had been obvious that the MiG-21 would be more useful if it could be fitted with radar. In particular this would enable it to serve as an interceptor for the IA-PVO. In 1957 the only new types of aircraft in production for the PVO had been designed by Sukhoi and Yakovlev. By this time several electronics design teams had radar installations which could be fitted into the MiG-21, and in late 1957 Mikoyan began collabo-



Ye-6V/2. (OKB)

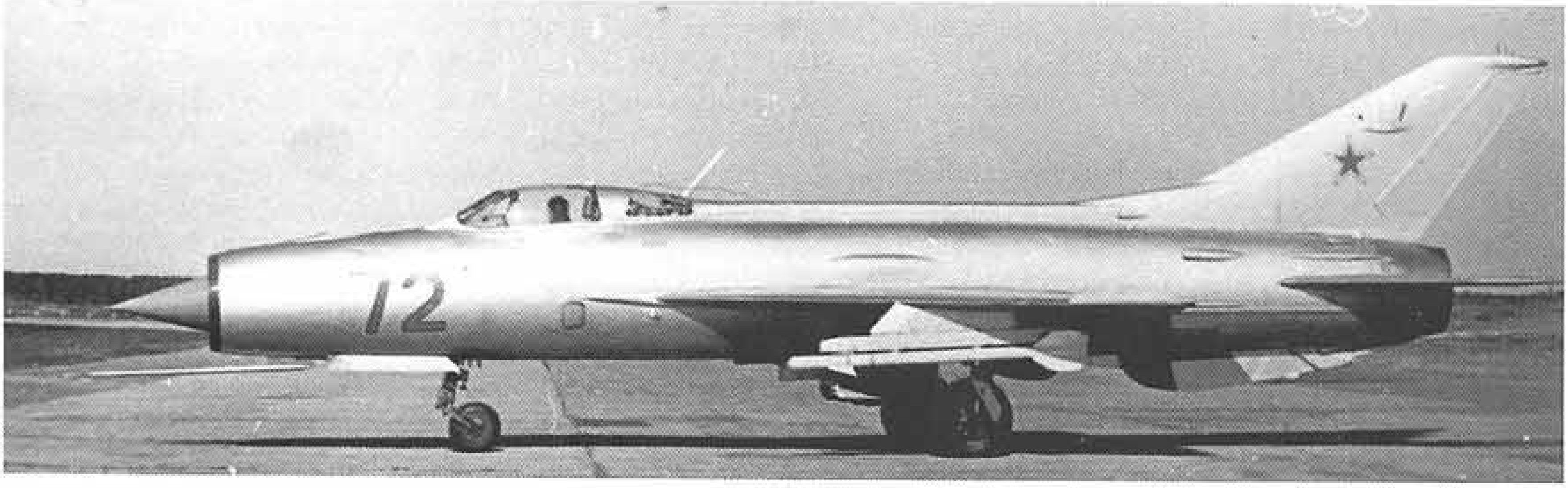
rating with the Nenyartovich KB to equip a new MiG-21 version designated Ye-7 with the TsD-30T, a radar in the *Sapfir* (sapphire) family.

By this time the OKB had considerable experience with nose inlets with a central cone large enough to house a search/track radar antenna. The main difficulties with the MiG-21 were how to arrange for variable-geometry (by sliding either the cone or the surrounding inlet lip) and how to avoid the centre of gravity migrating too far forwards. By removing the remaining gun, and rearrangement of equipment, it was found possible not only to install the radar but also possibly an additional fuel tank behind the cockpit. This significantly increased normal loaded weight, but maximum weight with a drop tank was already near the limit, especially as it had been decided to restress the structure to a load factor of 7.8. However, to enable the new interceptor version to operate from IA-PVO airbases, with poor paving, the mainwheels were enlarged to the KT-50/2 type with tyres 800 × 200mm, inflated to the reduced pressure of 8.08kg/sq cm (115lb/sq in). This demanded considerably larger wheel-bay blisters above and below the wing.

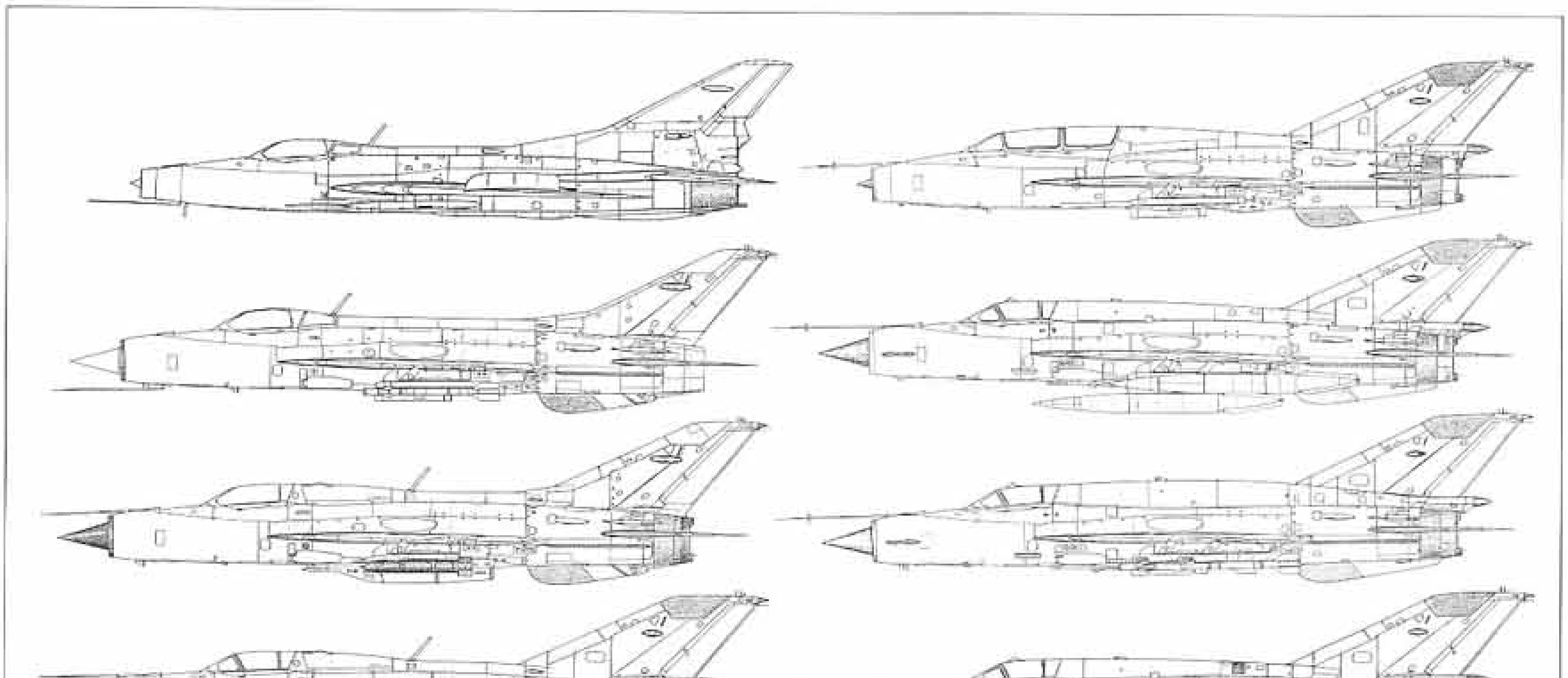
In 1958 OKB-155 received a contract for three Ye-7 prototypes. Each was based on the Ye-6T, with the KAP-1 autopilot, plus attachments at Frames 25 and 28 for SU-1500 assisted-takeoff rockets. Eliminating the guns enabled the forward airbrakes to be simplified, and these were also enlarged to 0.422sq m (4.54sq ft) each.

Though equipped with a receiver for the *Vozdukh*-1 (air-1) ground-control network, it was essential for the interceptor to be able to fly safely at night and in bad weather, and to find and destroy targets autonomously. This called for not only the radar but also KSI (Tacan-type) navigation, an improved *Lazur* beam/beacon receiver, a waveform receiver and the SOD-57M decimetric responder, as well as the existing SRO-2 *Khrom* IFF, *Sirena*-2 RWR, MRP-56P marker receiver, RV-3 radar altimeter and RSIU-5V radio.

To accommodate the radar the nose was redesigned. The surrounding structure was enlarged to a lip



Ye-7/2. (Yefim Gordon archive)



From top left, reading down: Ye-50-3; Ye-7/2; MiG-21PF; MiG-21PFM; MiG-21US; MiG-21SM; MiG-21SMT; MiG-21R with Type-D pod (inset, Type-R pod).

diameter increased from 690mm (27⅛in) to 870mm (34¼in), and 113mm (4.5in) longer. The enlarged centrebody was mainly of D16-T, but with magnesium-alloy rings as in the previous bigger MiG interceptors. The forward cone was of Oswatitsch three-angle shape, with its axis inclined 3° downwards. Made of glassfibre, it translated on four beams with needle-roller bearings, driven by the more powerful UVD-2M hydraulic control system. At the base of the cone was a bleed ring through which boundary-layer air could be sucked by aft-facing ejectors above and below the nose. This airflow, considerable at high airspeeds, was controlled by pipes and deflectors to cool the radar, but at over Mach 1.35 the air itself was too hot to be useful and so it could be diverted past the radar by pneumatically operated valves.

Ye-7/1, callsign 'Red 71', was first flown by Ostapenko on 10 August 1958. To get it into the air quickly it did not have the extended-chord fin nor the planned additional fuel tank, and the nose carried a representative mass in place of the radar. It also had the original PVD boom, and the longer nose made it impossible to hinge this up out of the way on the ground. Small pointed pods were added to the wingtips.

The other two interceptor prototypes likewise lacked the larger fin and extra tank, but waited on the ground throughout 1959 for operative radar. With this installed the Ye-7/2, callsign 'Red 72', at last began factory testing in the hands of Ostapenko and Kravtsov on 18 January 1960. Ye-7/3 was fitted with the larger fin, and it also introduced two new modifications. One was the parabrake tube under the rudder, instead of under the fuselage, as tested on the Ye-6Vs. This deployed quicker and was more effective, reducing the landing run. The other was a modified tail end to the fuselage with the final ring stiffened by strips of high-nickel alloy riveted round the top and bottom, leaving a gap on each side. Both modifications became standard on future versions.

Ye-7 factory testing was completed on 8 May 1960, by which time the Gor'kiy factory was already tooling up for production of the radar-equipped aircraft, which was designated MiG-21P (*perekhvatchik*, interceptor). The production radar was designated RP-21 *Sapfir*, operable in modes called SEARCH, ACQUISITION (locked-on), PURSUIT (tracking) and TAKING AIM (fire control). The MiG-21P was fitted with all the latest features including the larger fin. As an alternative to the R-3S missiles it was possible to carry bombs or rockets, which could be aimed by the PKI-1 collimator in the radar fire-control system, using it as a simple optical sight.

No series MiG-21P aircraft were built, because two further modifications, tested on additional prototypes, were imminent. The three Ye-7 prototypes had an internal fuel capacity of 2,380 litres (523.5gal), fractionally less than before. Short range and endurance were even more of a handicap to a bad-weather interceptor than to a day fighter, and the Ye-66A had shown that it was practical to add extra fuel behind the cockpit. First flown in August 1962, the Ye-7/4, callsign 'Red 74', did even better by having two extra tanks, under an enlarged spine longer than that of the Ye-66A. The extra 370 litres (81.3gal) brought total capacity up to 2,750 litres (605gal).

The Ye-7/4 was thus the first prototype of the MiG-21PF, described next. It was the first to have the very different appearance of the mass-production interceptor, with the wide-chord fin, a larger fairing behind a reprofiled canopy and the radio mast amidships. It also introduced the PVD-5 air-data boom mounted at the top of the nose, where pilots found it a useful indicator of angle of attack and drift. Where the PVD had previously been there now appeared the downwards-hemisphere

Ye-7/2. (Yefim Gordon archive)

triple-rod antennas of SRO-2M *Khrom-Nikel* IFF. Yet another new feature tested on Ye-7/4 was an AOA indicator on the left side of the nose. Designated DUA-3A, this was a simple weathervane mounted on a horizontal electric potentiometer shaft on a streamlined platform to place it beyond the boundary layer. Despite urgent appeals from user regiments, this was not to become standard until the MiG-21R of 1965.

Ye-7 data varied between aircraft. Dimensions and weights were almost identical to those of the MiG-21PF, and performance was in most respects the same as for the MiG-21F-13. The only significant changes were a slight reduction in rate of climb, an increase in range to 1,600km (994 miles) on internal fuel, and a reduction in landing run (because of the improved drag chute) to 850m (2,789ft). The ASCC called aircraft with this overall appearance 'Fishbed-D'.

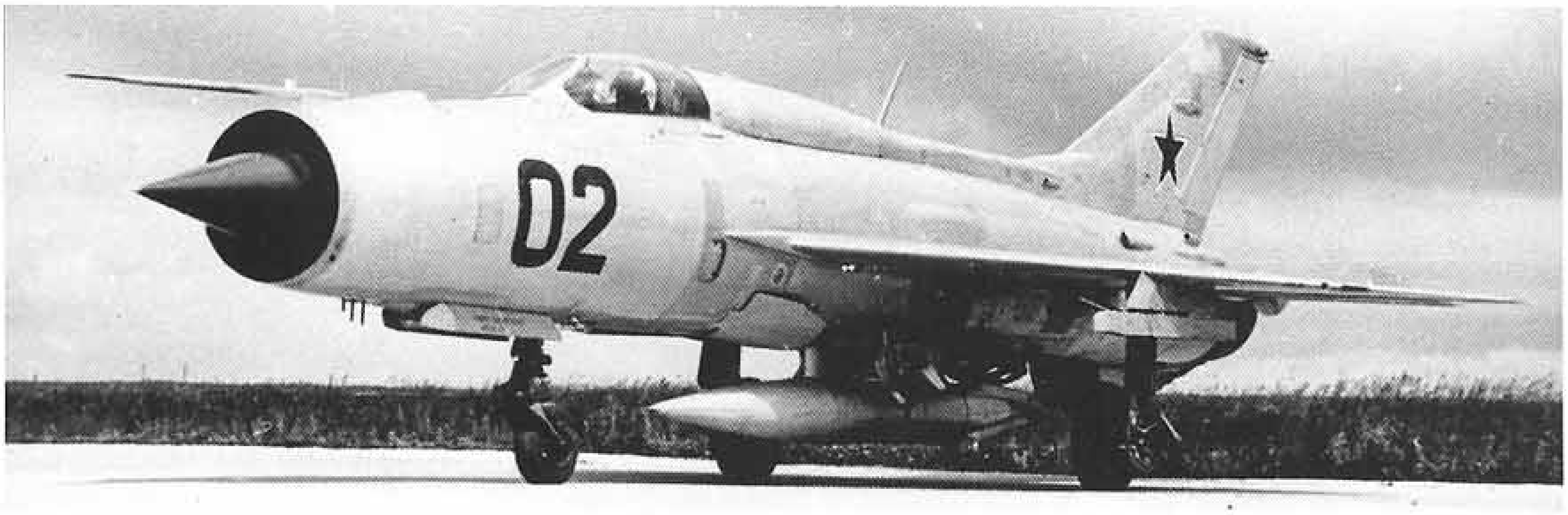
MiG-21PF, Ye-76, 76

Before true production interceptors appeared it had been decided to switch to the R-11F2-300 engine, which had been fitted to the Ye-66A and to all prototypes from the Ye-7/3 onwards (close relatives powered Yak-28 development aircraft). Rated at 3,950kg (8,708lb) dry and 6,120kg (13,492lb) with afterburner, this helped to maintain performance despite steadily increasing weights. With this engine the *Izdeliye* number became 76 and the Service designation MiG-21PF.

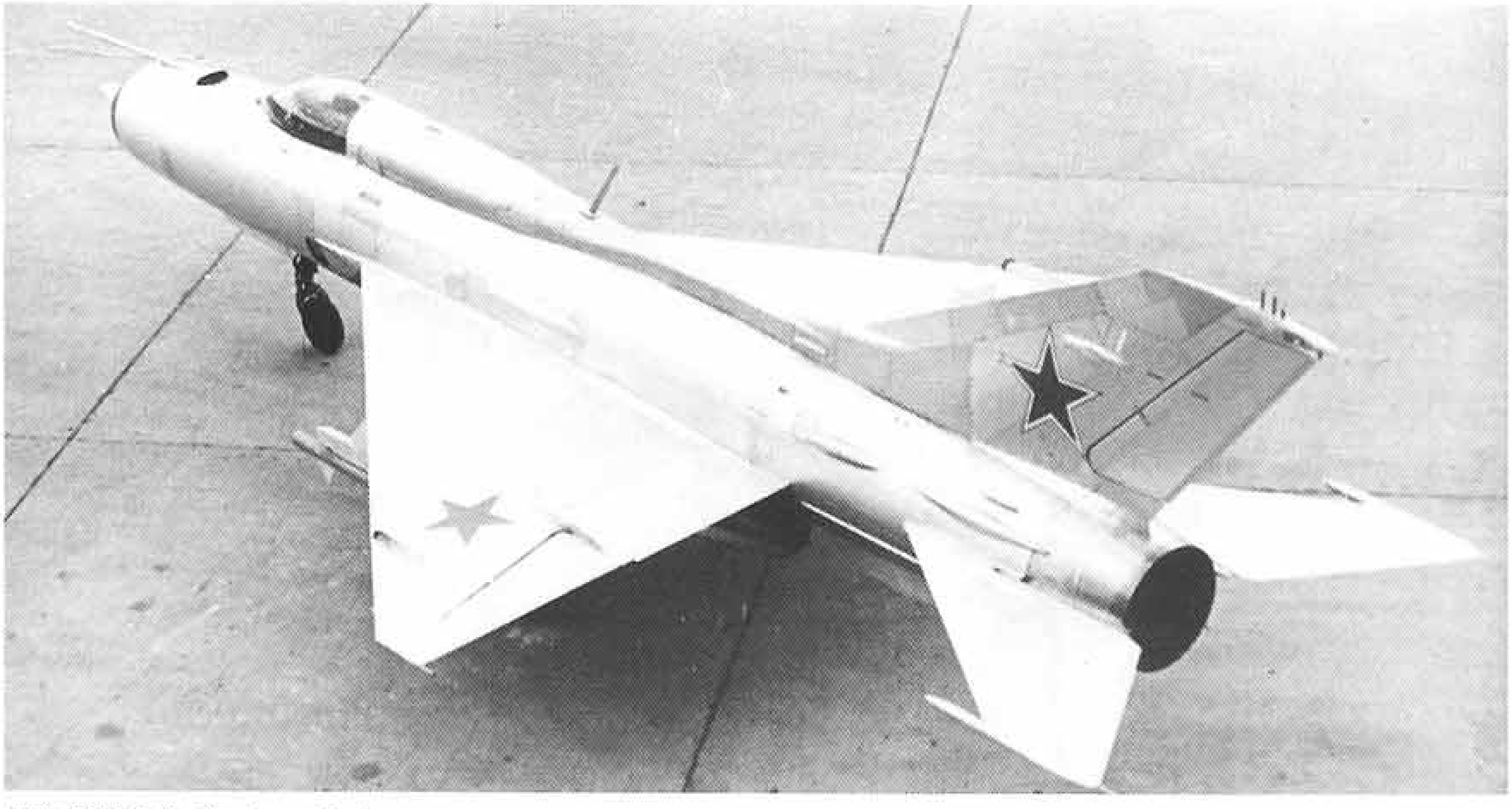
Gor'kiy began series production in early 1962, and by 1964 had delivered more than twice as many PFs as it had of the day-fighter version. These went to both Frontal Aviation and IA-PVO defence regiments. All the early batches retained the original parabrake installation, beside the underfin.

Despite the fact that many customer air forces were unhappy at the idea of a fighter with no gun, between 1964 and 1968 the *Znamya Truda* factory delivered a large number of PF interceptors to all the Warsaw Pact air forces, followed by Egypt, Ethiopia, Sudan, North Vietnam, North Korea, North Yemen and Cuba. Most of these aircraft had a lower standard of avionics, and the Vietnamese aircraft, locally designated MiG-21PF-V, were specially modified for a hot and moist environment.

The initial series of State tests at NII-VVS were not completed until 1963, and further testing followed. In 1966 one aircraft became available



Early (possibly the first or the second) MiG-21PF. (OKB)



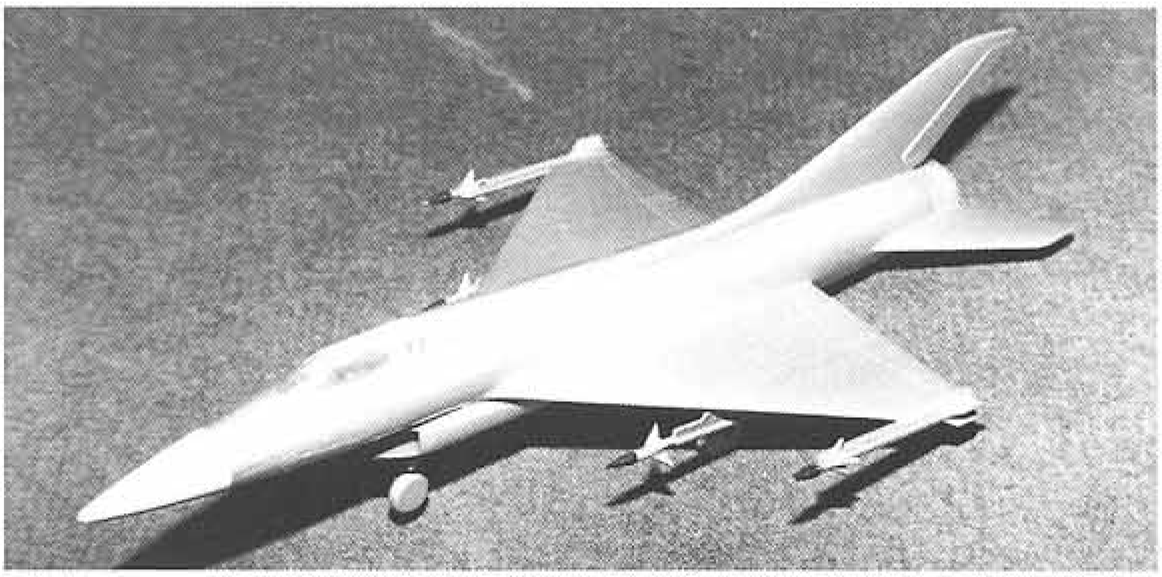
MiG-21PF. (Yefim Gordon archive)

for a set of women's records. On 16 September 1966 Marina Solovyeva flew a 500km circuit at 2,062km/h (1,281mph), using full afterburner for the 15 minutes necessary. On 11 October Yevginiya Martova flew a 2,000km circuit at 900.26km/h (559.4mph). On 18 February 1967 Martova flew a 100km circuit at 2,128.7km/h (1,322.75mph). Finally, on 28 March Lydia Zaitseva, who had already set an altitude record with a MiG-21UM, flew a 1,000km circuit at 1,298.16km/h (806.7mph). In each case the aircraft was reported to the FAI as 'Ye-76 with TRD 37F engine'. The ASCC name was 'Fishbed-D'.

Span 7.154m (23ft 5⅝in); length 14.48m (47ft 6in), (excluding PVD) 14.1m (46ft 3⅛in); (fuselage, from inlet lip) 12.285m (40ft 3⅝in); wing area 23sq m (247.6sq ft).

Weight empty 5,256kg (11,587lb); internal fuel 2,280kg (5,026lb); weight loaded 7,750kg (17,086lb); maximum loaded 8,770kg (19,334lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,175km/h (1,352mph, Mach 2.047) at 13,000m (42,651ft); climb to 10,000m (32,808ft) 6.2min, to 18,500m (60,696ft) 8min; service ceiling 19,000m (62,340ft); range (clean) 1,400km (870 miles), (tank) 1,900km (1,180 miles); take-off run 900m (2,953ft); landing speed 280km/h (174mph); landing run 850m (2,789ft).

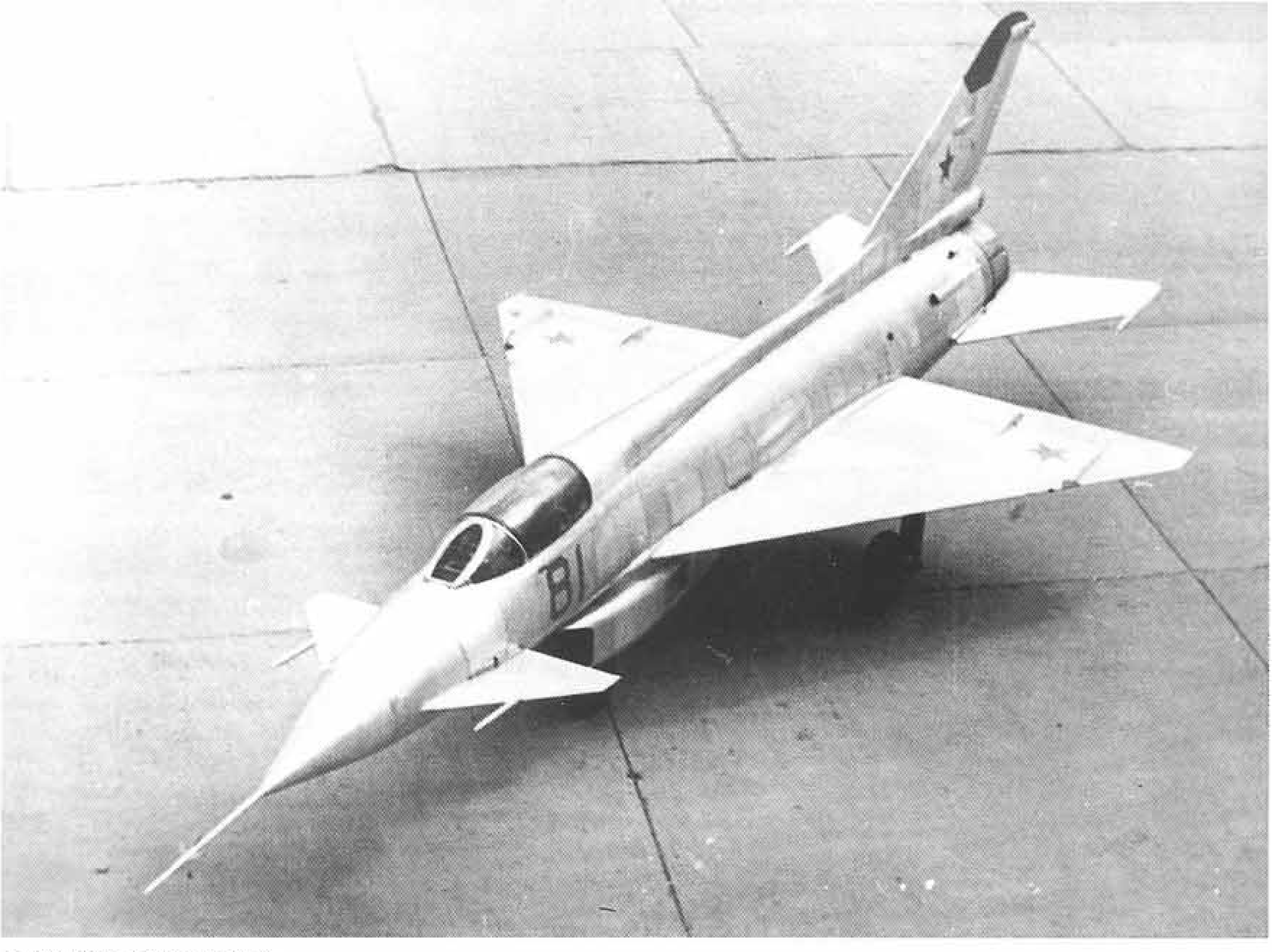


Model of Ye-8 project. (photograph by Yefim Gordon)

Ye-8

So different as hardly to be considered a MiG-21 at all, this grossly modified aircraft was the result of a Kremlin decree of spring 1961 calling for 'a version of the MiG-21 capable of destroying hostile aircraft at night or in bad weather'. It was intended to enter service as the MiG-23.

The key feature was the use of the Volkov *Sapfir*-21 radar (later given Service designation RP-22). This was tailored to twin-engined aircraft, and there was no evident way its antenna diameter could be reduced to fit inside a MiG-21 inlet cone, though studies were made with larger cones. Later a smaller antenna was found practical, but the Ye-8 design team



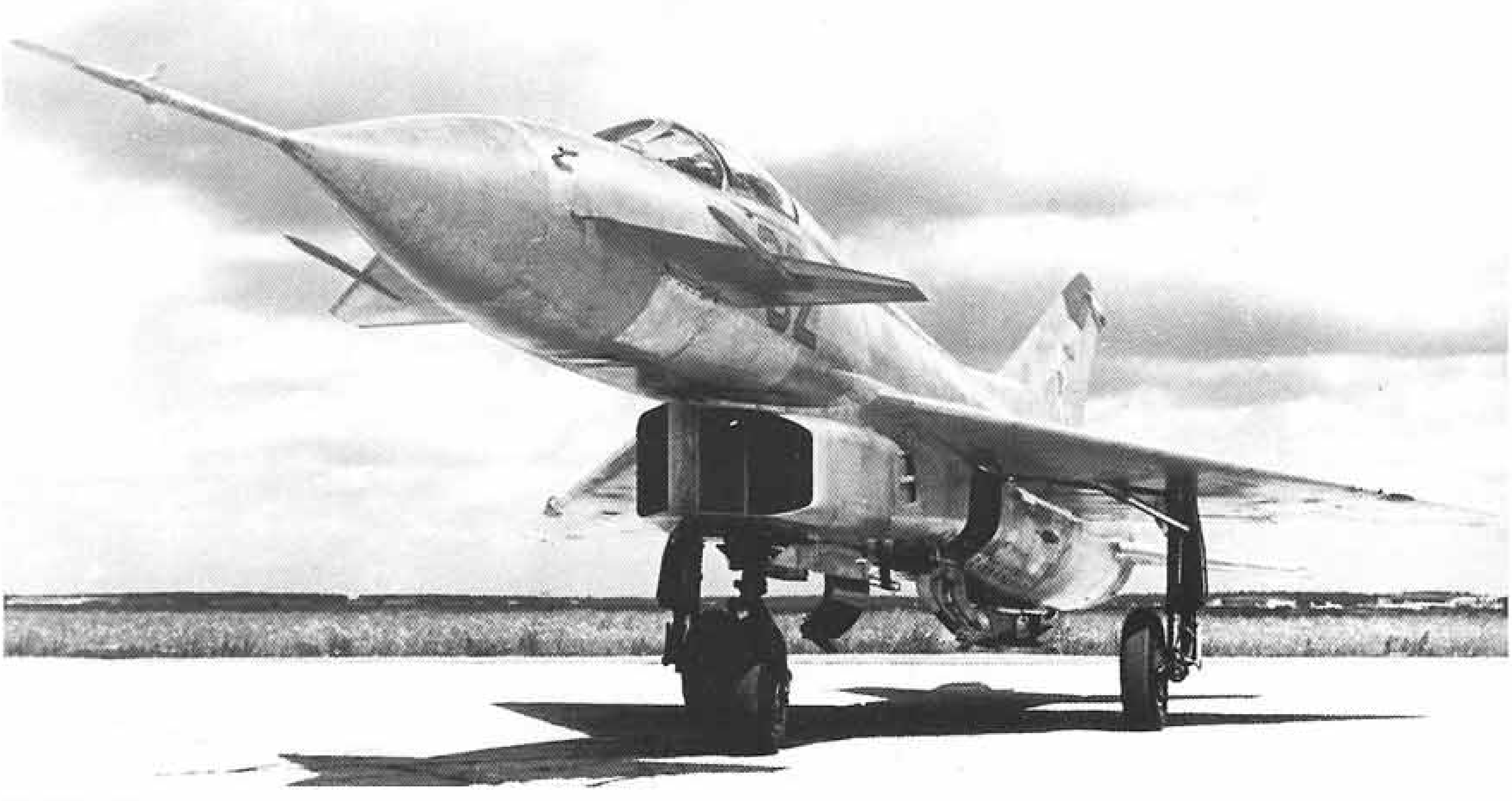
Ye-8/1. (Yefim Gordon archive)

decided there were advantages in using a variable-geometry two-dimensional inlet well back under the fuselage. This had a vertical sharp splitter with three Oswatitsch angles, from which the ducts passed on each side of the nosewheel bay and then sharply curved up to the axis of the fuselage. Each duct had an auxiliary inlet and bleed flap just under the wing root. The new nose landing-gear unit had to retract backwards.

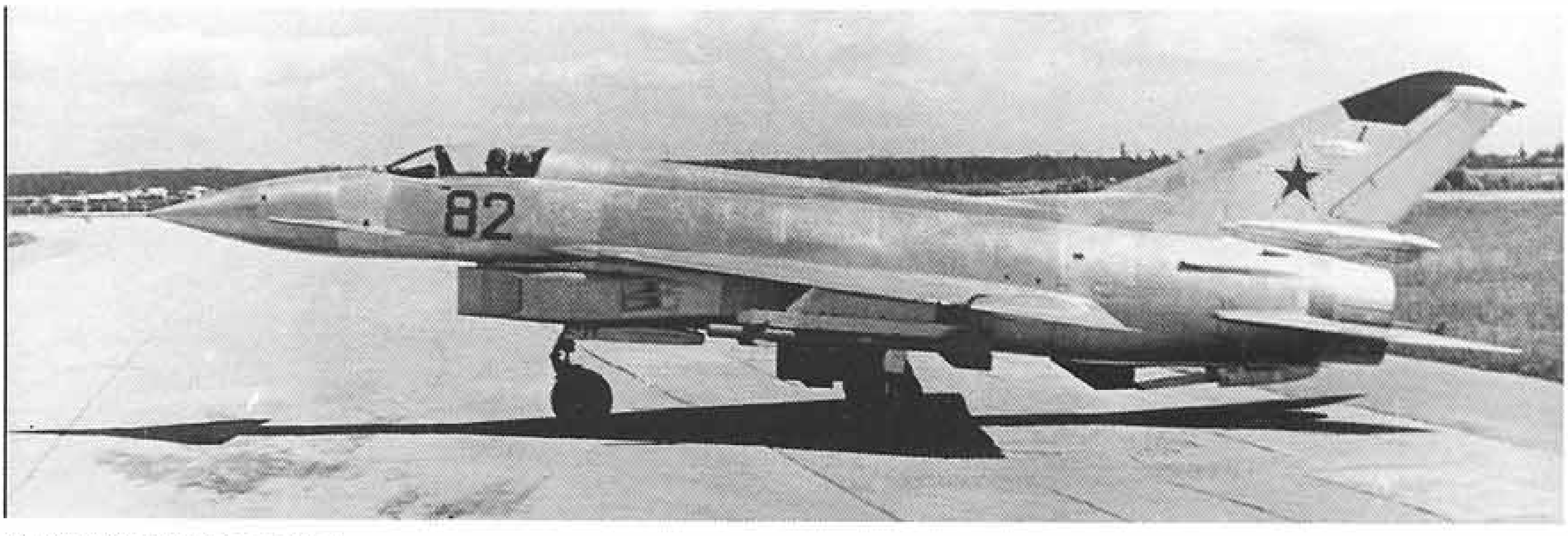
This left the nose free for an optimized radar installation. On each side was a canard foreplane, a *destabilizator* similar to that tested on the Ye-6T/3 with a span of 2.6m (102.4in), normally free to weathercock but locked at zero incidence at Mach 1 and over. Their effect was dramatic: at 15,000m (49,200ft) they enabled sustained turn acceleration to be increased from 2.5g to 5.1g, and they substantially increased maximum lift coefficient in all flight regimes. The vertical tail was similar to the Ye-7/8, the tailplanes were mounted 135mm (5.3in) lower than normal, and the underfin was greatly enlarged and made to hinge sideways whenever the landing gear was extended (as on the unrelated MiG-23 much later).

Having created a very different aircraft the designers went the whole way and fitted a new engine fed by integral tankage throughout. The engine was a much-modified R-11 called R-21, developed by N Metskhvarishvili. Inlet diameter was increased from 772mm to 845mm (33.27in), the greater mass flow increasing dry and afterburning ratings to 4,700kg (10,362lb) and 7,200kg (15,873lb), respectively. The totally redesigned tankage of five integral compartments in the fuselage and four in the wings had a capacity increased to 3,200 litres (704gal). Provision for drop tanks was retained.

Almost every part of the Ye-8 was different. The canopy had a fixed front section with an optically flat windscreen, while the main hood hinged to the right. Behind it was a reprofiled spine leading to a glassfibre dorsal fin and a large tube for a new design of parabrake. The seat was the KM-1, and half the exterior skin of the fuselage comprised access doors and removable panels. Armament remained just two K-13 (R-3S) missiles.



Ye-8/2. (Yefim Gordon archive)



Ye-8/2. (Yefim Gordon archive)

Orders were placed for two prototypes. The OKB had high hopes that the Ye-8 would prove a true world-beater, the only small problem being the short wheelbase of 3.35m (11ft), which made the aircraft nod uncomfortably on rough ground. Unfortunately for Mikoyan, the programme was disrupted by the immaturity of the engine. With an inert mass instead of the radar, Ye-8/1 first flew in the hands of chief test pilot Mosolov on 5 March 1962. The engine gave repeated trouble, and on Flight 40 on 11 September 1962 the third HP compressor stage disintegrated and the pieces were not contained. Mosolov was injured on ejection and again on hitting the ground.

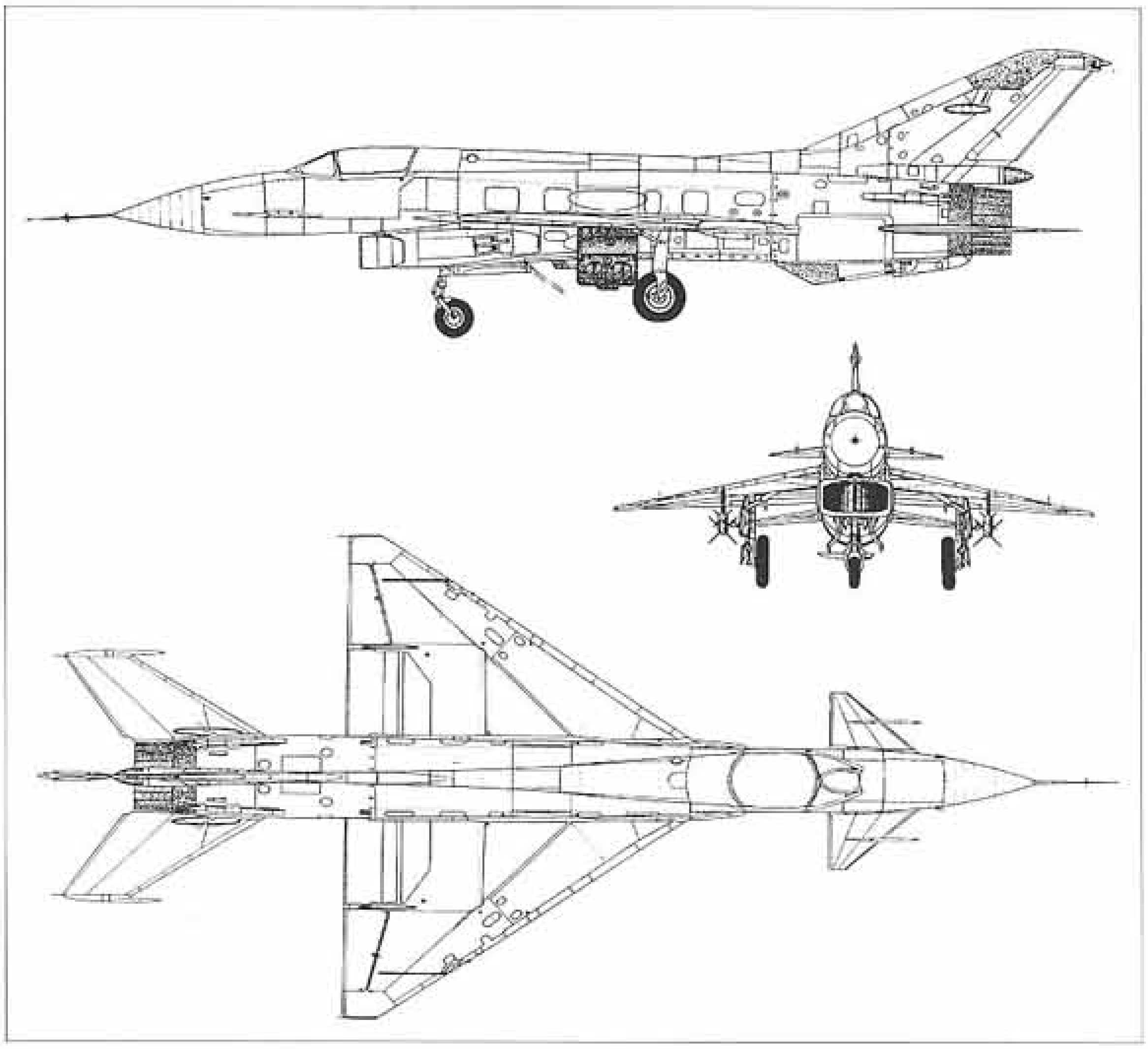
The Ye-8/2 had blown flaps (described later) and other changes. Fedotov made thirteen flights in it between 29 June and 4 September 1962, but with great reluctance the unreliable engine resulted in the Ye-8 being abandoned. This type was unknown in the West, and so never received an ASCC name.

Two derivatives were never built. The Ye-8M was a 1962 project with wheel/ski landing gear. The Ye-8F was a 1963 proposal for a STOL version with two RD-36-35 lift turbojets. The data below are for the Ye-8.

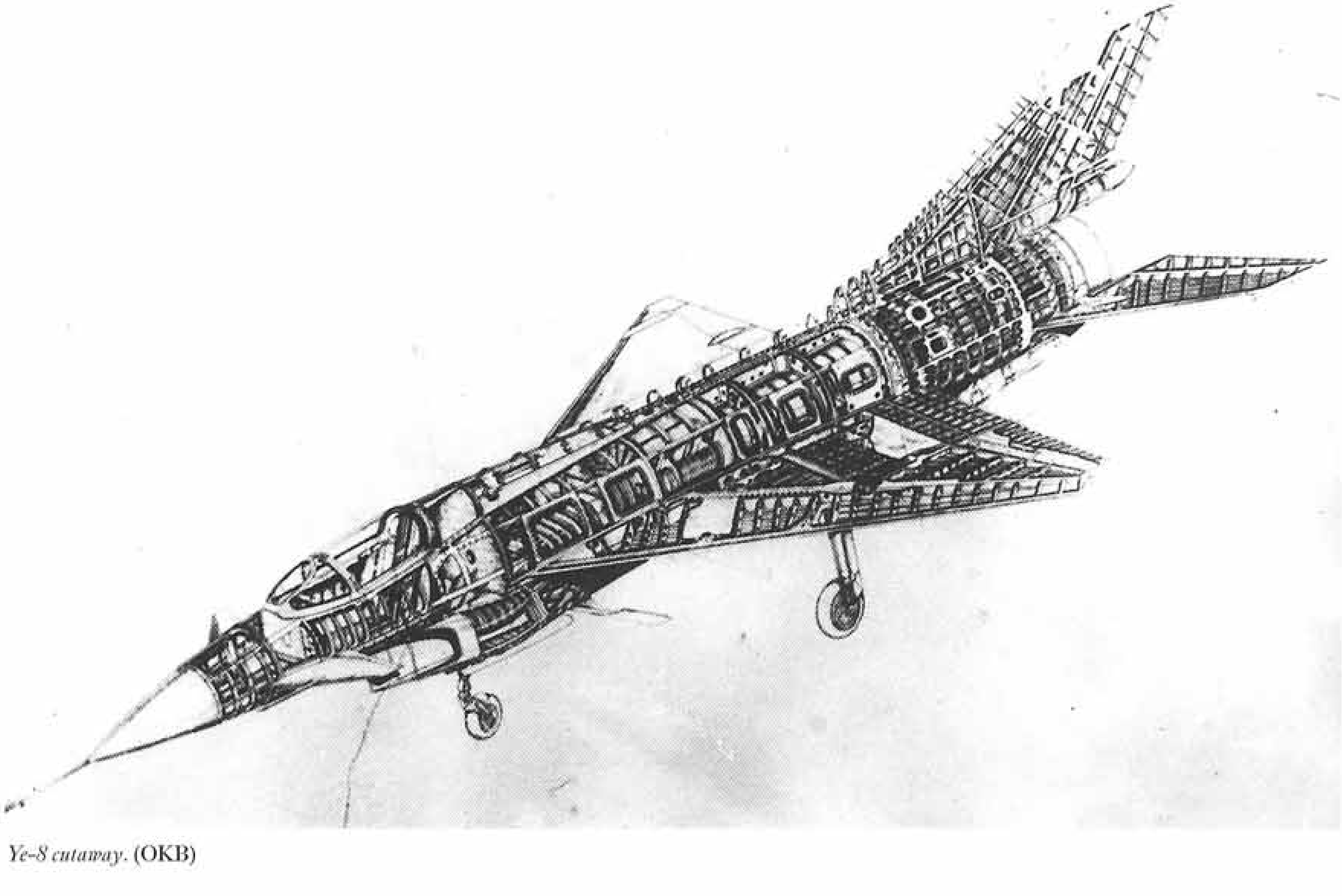
Span 7.154m (23ft 5⅝in); length 16.24m (53ft 3⅜in), (excluding PVD) 14.90m (48ft 10⅝in); wing area 23sq m (247.6sq ft).

Weight empty (Ye-8/1) 5,105kg (11,254lb); internal fuel 2,655kg (5,853lb); maximum weight loaded 8,200kg (18,078lb).

Maximum speed 2,230km/h (1,386mph, Mach 2.1) at high altitude; climb to 18,000m (59,055ft) 5.9min; service ceiling 20,300m (66,600ft); range not measured; takeoff run 835m (2,740ft); landing run 850m (2,789ft).



Ye-8/1.



Ye-8 cutaway. (OKB)

MiG-21PFS, Ye-7SPS

From 1957 the MiG-21 designers had ceaselessly searched for ways to reduce the fighter's field length of some 1.6km (1 mile), which was considered unacceptably long. From 1954 some US fighters had been fitted with blown flaps, and in 1959 the OKB, CAHI, CIAM and the Tumanskiy KB collaborated in investigating what such flaps could do for the MiG-21.

Previous MiG-21s had typical Soviet track-mounted slotted flaps, which in ideal conditions could achieve a lift coefficient of about 2. The blown flap is not track-mounted but just hinged to the wing. When rotated downwards the airflow at first stays 'attached', following the curved upper surface of the flap, but it very soon stalls, breaking away in turbulence and destroying the flap's lift. To prevent this, hot high-pressure air is bled from the engine's compressor and piped to a thin aft-facing slit just above the flap's leading edge. It issues at supersonic speed as a thin sheet across the top of the flap. This forces the flow to stay 'attached' even to a flap angle of 90°. Early tests showed that with blown flaps the MiG-21 could reach a lift coefficient of 3.

Called SPS (*sduv pogranichnogo sloya*, boundary-layer blowing), this does little for takeoff, when flaps might increase lift but would be counter-productive in simultaneously increasing drag. Their real advantage is in enabling the landing approach to be slower, because with the engine at quite high power and flap blowing in operation the lift at low speeds is greatly enhanced. Of course, the engine must be modified to supply the enormous bleed airflow. With this in operation, the fuel supply must be cut back to match the greatly reduced airflow through the combustion chamber and turbines, which would otherwise overheat. The modified engine was designated R-11F2S-300.

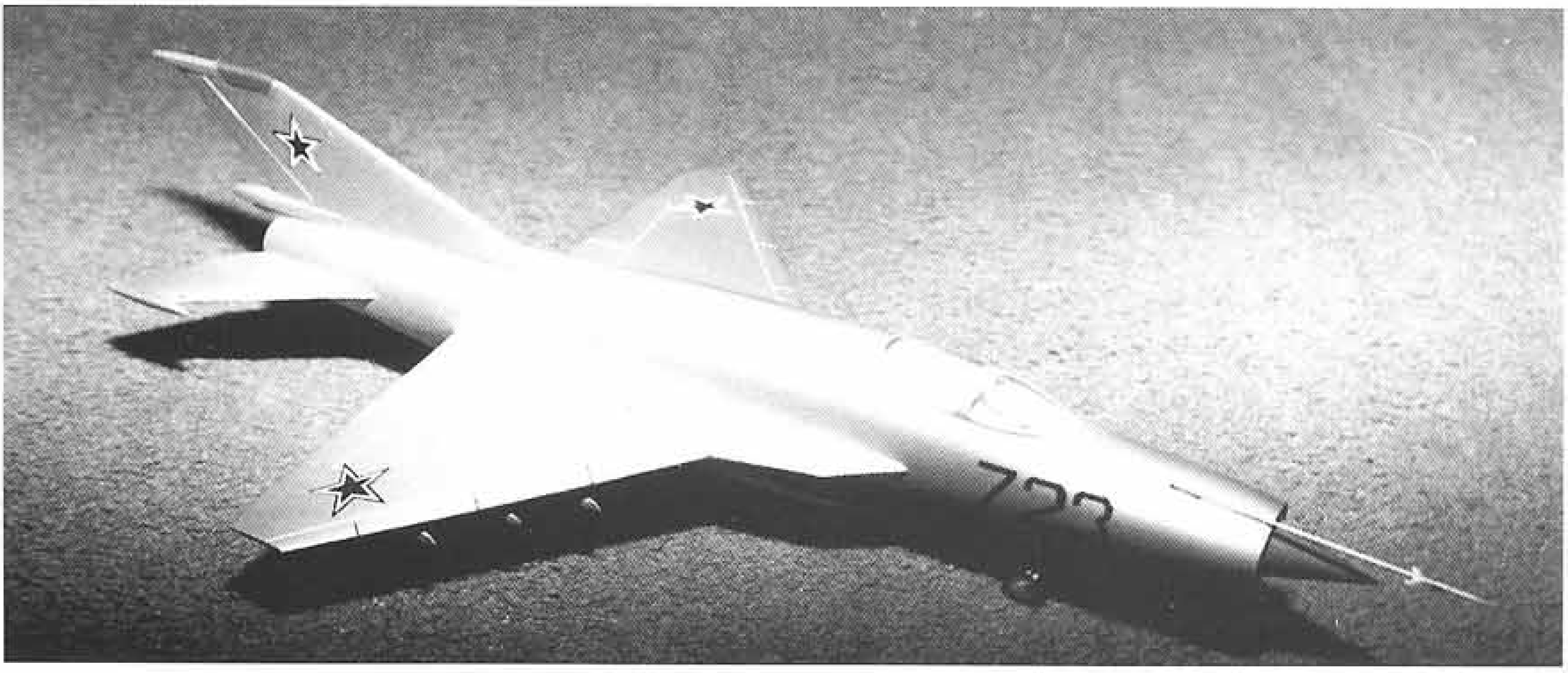
By chance the MiG-21 was an ideal candidate for flap blowing. The engine bleed connection was adjacent to the inboard end of the rear wing beam (transverse spar) ahead of the flap. With only a small kink, a pipe of heat-resistant stainless steel was joined to the carefully designed blowing slit behind the beam from Ribs 1 to 6. The gap between the slit and the extended flap was made 2.2±0.2mm, or about 0.1in. Each flap was slightly reduced in size, to 0.92sq m (9.9sq ft) instead of 0.935sq m, and driven by an actuator with tandem chambers in both hydraulic systems to 25° for takeoff and a maximum of 45° for landing. The piston rod was hinged to a bracket outboard of the midpoint of the flap's leading edge, and covered by a blister fairing. The only other distinguishing feature was a small rounded inspection panel just above the wing immediately ahead of Frame 28 (the fuselage break).

Tumanskiy finally qualified the R-11F2S-300 turbojet in 1961. Without blowing, the dry rating was unchanged at 3,900kg, but the afterburner was further improved with two pilot-selectable stages of operation to give a maximum takeoff thrust of 6,175kg (13,613lb). With variations, this was to be the engine of more MiG-21s than any other. It was distinguished by the large bleed connections amidships between the compressor and combustion chamber, protected by a pilot-controlled valve and safety venturi.

SPS was tested on several Ye-7s, called Ye-7SPS, and a MiG-21U. The main problems were that overshooting demanded sudden application of takeoff thrust, and stopping blowing immediately drastically reduced the lift, and that in landing configuration selection of blowing caused the aircraft to pitch nose-down whilst simultaneously suddenly rising some 200m (656ft). Perhaps with over-caution, the SPS on the aircraft in front-line service was for a long time locked inoperative (when the plain flaps were inferior to those previously fitted), and then hesitantly allowed to be used for landing, but only to the takeoff angle of 25°.

The Gor'kiy plant did not start building the blown-flap MiG-21PFS until 1964. This also standardized the long-awaited upper parabrake tube above the end of the fuselage, with twin clamshell doors. Streamed from it was the new PT-21UK drag canopy of cruciform shape with six parallel gores along each of the two axes at 90°. This partnered SPS in enabling the MiG-21 to use airstrips of under 1km (3,280ft), while twin SU-1500 or SPRD-99 rockets (the latter rated at 2,500kg, 5,511lb, each for 17sec) shortened the takeoff. Fuel capacity remained 2,750 litres.

By the time the MiG-21PFS was in production further modifications



Model of MiG-21Sh Shturmovik *(ground-attack) project, which was never built.* (photograph by Yefim Gordon) were in the pipeline. Accordingly, Gor'kiy produced this version only for about a month, all aircraft going to one regiment. As external appearance was little changed, the ASCC name remained 'Fishbed-D'. Data are similar to those of the MiG-21PFM.

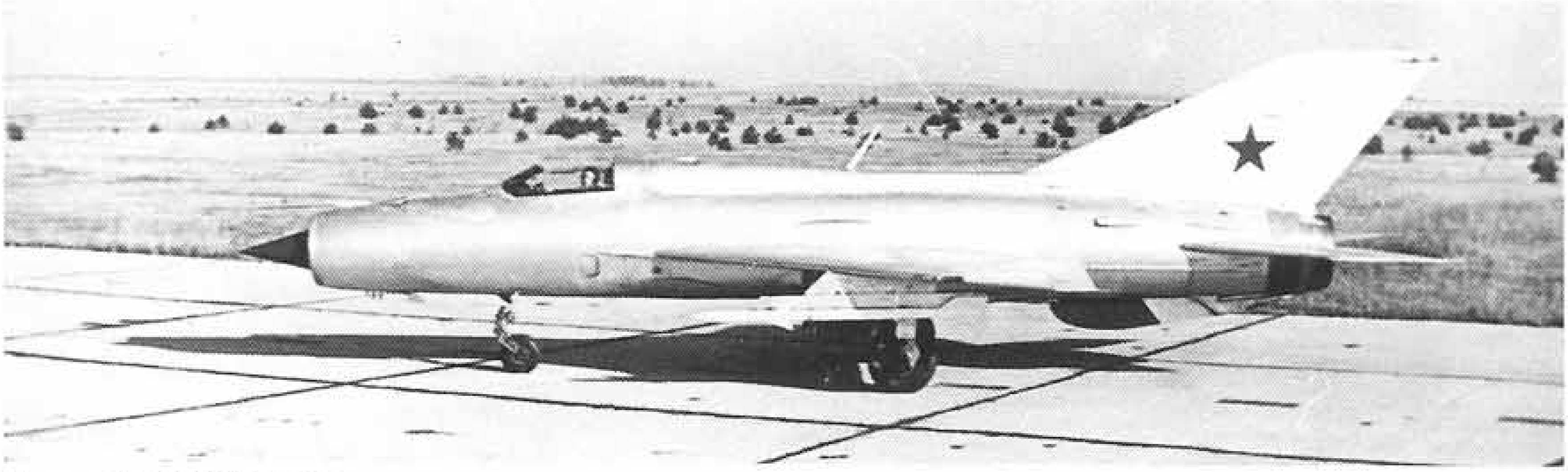
MiG-21PFM, 77, 94

This major production version combined SPS with a growing number of new features. The most obvious was yet a further increase in the chord of the fin, to give the remarkable area for the combined fin and rudder of 5.32sq m (57.27sq ft). The new fin had a leading edge of unchanged sweep angle extending in a straight line from the forward tip of the previous dorsal fin to a much broader top. It considerably reduced the endemic problem of compressor surges and stalls.

The radar was replaced by the RP-21M, which could be switched to provide a guidance signal for command-guidance missiles. An obsolescent missile available in large numbers, RS-2U, had previously been compatible with earlier MiG interceptors, which by the 1960s were tired and costly to maintain, so many MiG-21PFMs were used to help fire off the missile stocks. More important was that the new radar was also compatible with the Kh-23 ground-attack missile, so for the first time a MiG pilot could train in precision surface attack.

Regarded by some as even more welcome was the optional addition of a gun. The powerful new GSh-23L twin-barrel 23mm weapon was installed in a package designated GP-9, together with 200 rounds, a self-contained cooling system and its electrical control system. The MiG-21PFM was designed with attachments enabling the GP-9 to be scabbed under the fuselage in an installation tested on Ye-7s. To improve shooting accuracy the sight was changed to the ASP-PF-21. Other upgrades included the *Sirena*-3M RWR, with the aft-facing passive receivers on the rear tips of the two GIK magnetometer blisters on each side of the fin. The IFF remained SRO-2M *Khrom-Nikel*. This version was *Izdeliye* 77, with Service designation MiG-21PFM. Production at the Gor'kiy factory began in late 1964.

It had been planned to fit the new KM-1 seat from the outset, but this did not become available until the fifteenth MiG-21PFM. The KM-1 was an almost completely new design, with



Prototype MiG-21PFM. (OKB)

Prototype MiG-21PFM. (Yefim Gordon archive)

MiG-21PFM Type 94. (Yefim Gordon archive)

no altitude limits but with a lower limit of airspeed of 130km/h (81mph). It no longer needed the canopy as a windbreak, and as this scheme had several times failed in service, the OKB threw it out and from the fifteenth MiG-21PFM there was a normal fixed windscreen and a canopy hinged to starboard. The new seat required slight rearward movement of the aft cockpit bulkhead, cutting into Tank 1 to reduce internal fuel to 2,650 litres (583gal).

These changes resulted in the new *Izdeliye* number of 94. In the course of MiG-21PFM production the nosewheel was changed to the KT-102, with a more powerful brake of disc type. At an airshow in 1967 a series aircraft demonstrated every conceivable combination of dry/reheat/rockets takeoff and brakes/blowing/parachute landing, achieving a shortest takeoff run of 360m (1,181ft) and a shortest landing run of 420m (1,377ft). The ASCC names were 'Fishbed-E' (wide fin) and 'Fishbed-F' (wide fin and new cockpit canopy).

Dimensions as MiG-21PF.

Weight empty 5,383kg (11,867lb); internal fuel 2,200kg (4,850lb); weight loaded 7,820kg (17,240lb); maximum takeoff weight 9,080kg (20,018lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,230km/h (1,386mph, Mach 2.1) at 13,000m (42,651ft); climb to 18,500m (60,695ft) (with missiles) 8min; service ceiling 19,000m (62,340ft); range 1,300km (808 miles), (490lit tank) 1,670km (1,038 miles); takeoff run (no a.t.o.) 900m (2,953ft); landing speed (SPS, chute) 248km/h (154mph); landing run 550m (1,804ft).

MiG-21FL, 77

Often said to be a version of the MiG-21PF, this version of the MiG-21PFM (*Izdeliye* 77) was licensed to the Indian government in 1962. Assembly of parts supplied from the *Znamya Truda* factory began at Hindustan Aeronautics Ltd in 1965, and production at HAL continued in 1966, ending with the 196th aircraft in 1973. It involved a new group of factories at Nasik (airframe, assembly and flight test), Koraput (engines) and Hyderabad (avionics and instruments). Features included the very broad fin, R-11F-300 engine, the original seat and canopy, the simpler R-2L radar, provision for the GP-9 gun pack and increased fuel capacity of 2,900 litres (637.9gal). The ASCC name was 'Fishbed-E'. Data similar to MiG-21PFM.

MiG-21R, 94R

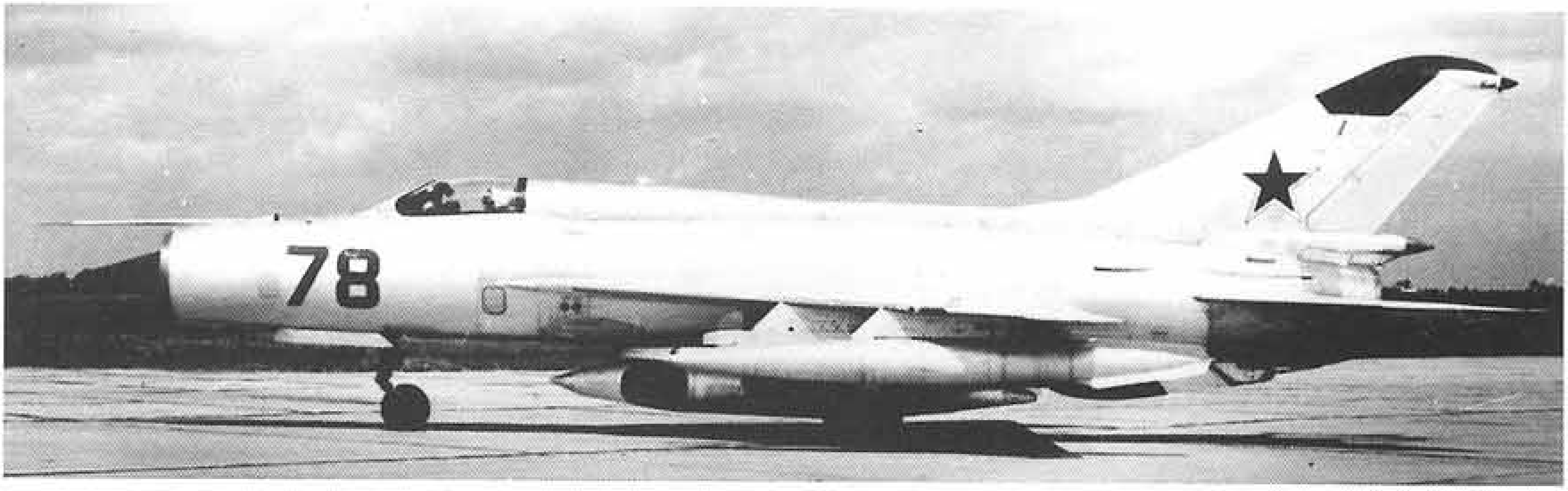
By the early 1960s the VVS had an increasingly urgent need for a modern tactical reconnaissance aircraft able to overfly battle areas at supersonic speed. By this time the MiG OKB had conducted extensive studies with reconnaissance versions of the MiG-21. After examining various internal installations of cameras and other sensors, it appeared that the optimum solution was to develop a series of different streamlined external pods, each housing a particular group of sensors according to the changing needs of the local commander.

Such a container had to be carried under the aircraft centreline, on a pylon which had previously been used for a drop tank. As combat radius was particularly important for a reconnaissance aircraft, the MiG designers proposed to partner the sensor container by up to four drop tanks. Thus, the reconnaissance aircraft needed an extra pair of wing pylons. This would also offer the alternative of carrying two tanks and two self-defence missiles.

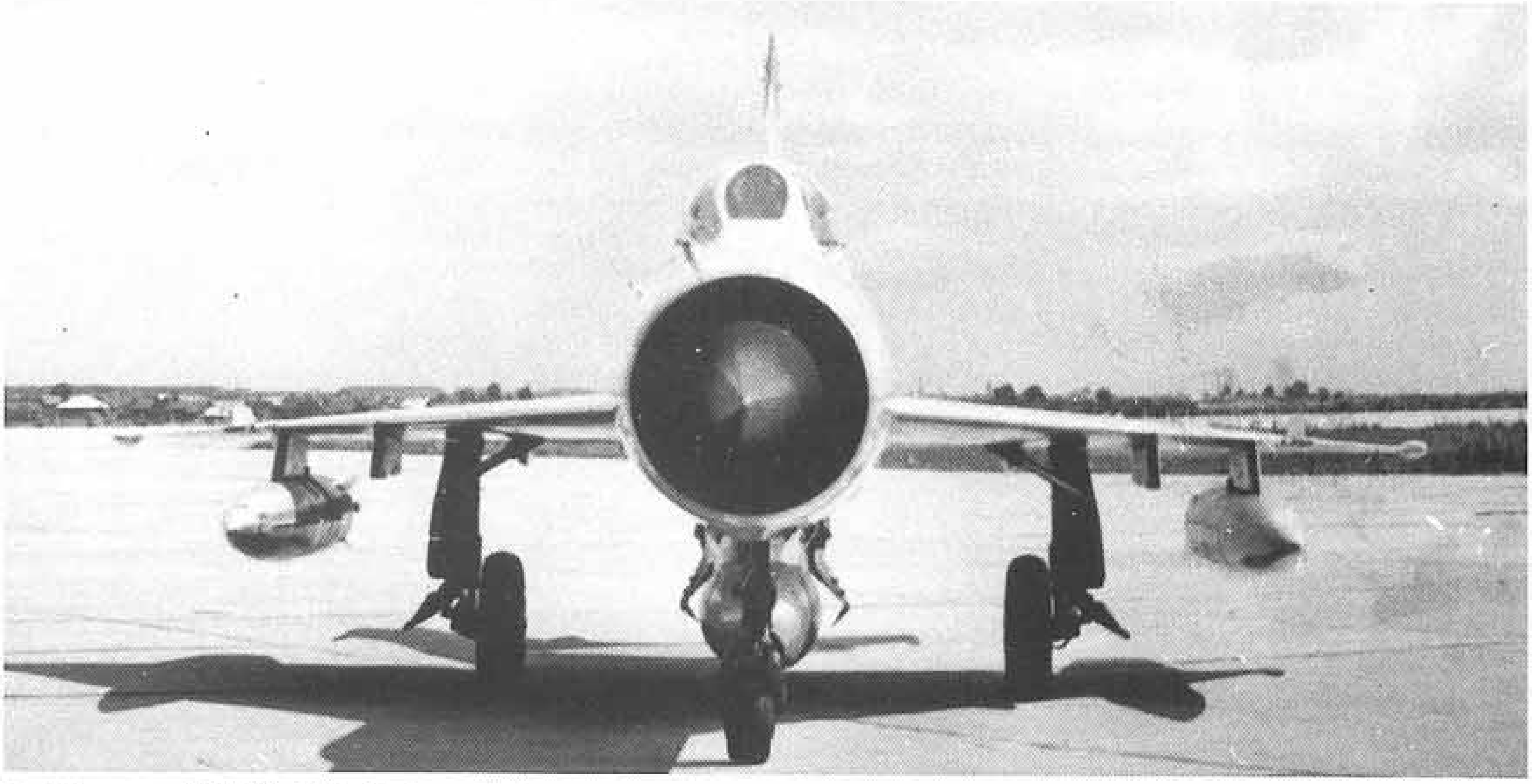
Having obtained contract cover, the Ye-7/8 prototype, callsign 'Red 78,' was built in 1961 with four wing hardpoints all plumbed for tanks. Features included the R-11F2S-300 engine with blown flaps, the SK seat and original canopy, the high PVD and parabrake, and a Ye-8 type fin, of much smaller chord than the MiG-21PFM and a round top with a large dielectric area housing the radio antenna.

The initial three types of sensor pod were designated D (day), N (night) and R (radio), and, though there were others, these were to become by far the most widely used by tactical regiments. The D pods invariably housed seven optical cameras, one looking ahead through a flat inclined window under the nose and the other six looking obliquely down in pairs on each side. The usual cameras were the AFA-39 and the AShTSh/AFA-SM for strip coverage to the horizon. A wide choice of film was available, and the N photo versions used IR types, as well as photoflashes for optical film. Both D and N pods usually carried an SPO-3R passive radar receiver, and an ASO-21 chaff/flare dispenser for self-protection. Later sensors included EO (TV) and IR linescan. A typical pod weighed 285kg (628lb).

The R containers were similar in size and invariably housed a SLAR (sideways-looking airborne radar) of the *Lira* (lyre) family, with antennas scanning on either one side or both. Comprehensive waveband coverage of hostile emitters was ensured by six radio/radar passive receivers coupled to recorders (usually the MS-61), while an AFA-39 camera was mounted under the nose (more streamlined than the window in the



Ye-7/8 prototype MiG-21R. (Yefim Gordon archive)



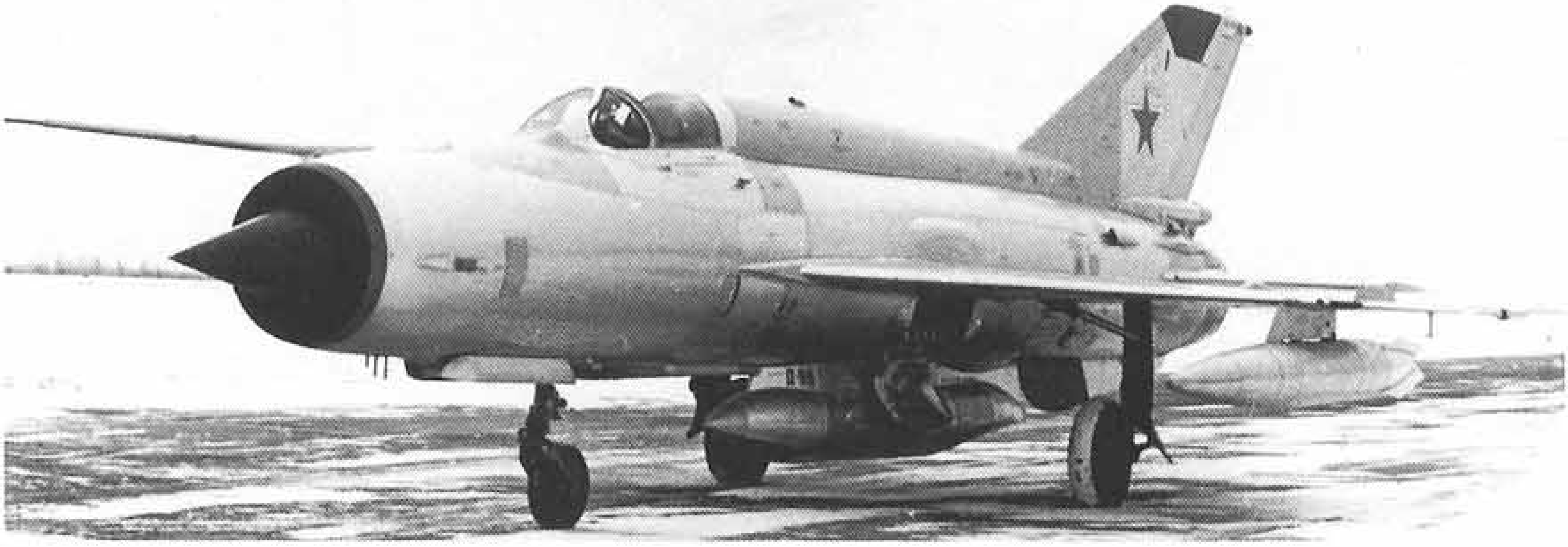
Ye-7/8 prototype MiG-21R. (Yefim Gordon archive)

D pod) and chaff/flare dispensers were housed at the rear. Other pods included the ED (from *efeer*, ether), packed with Elint and Comint intelligence receivers and recorders. Every pod was linked to the aircraft navigation system so that all intelligence could be pinpointed to a geographical location.

The SPO-3 passive system for detecting hostile emitters of all kinds was also served by additional antennas carried on small pods on the wingtips. Each had an antenna at the front, receiving over an arc of 135° from dead ahead, and one at the rear covering the same arc from astern; thus the two pods gave overlapping coverage over 360°. This system served a self-defence as well as an intelligence-gathering function, and the outputs were displayed in the cockpit as well as being fed to recorders.

MiG-21R. (Yefim Gordon archive)

After two years of testing, the build-standard of the series aircraft was settled in 1964. Service designation was MiG-21R and OKB designation 94R. This was one of the most important versions, built at Gor'kiy for seven years, 1965–71. This long period was because, uniquely, Gor'kiy also fulfilled all export orders for this version.



MiG-21R. (OKB)

Features included the very broad fin (standard from this time onwards), the KM-1 seat and new canopy, F2S engine and blown flaps, cruciform drag chute under the rudder, and the latest standard of avionics. The latter included two welcome new items. One was a full-authority autopilot, the AP-155. This could, if the need for evasive action permitted, hold a precise course and height during reconnaissance runs. The other was the DUA-3A AOA sensor on the left side of the nose, as tested on the Ye-7/4. The PVD boom was moved to the right side of the top of the nose, where it stayed in subsequent versions.

Visually, the most striking feature of the 94R was that the swollen spine was extended in a smooth gentle curve all the way back to the fin. This had little effect on area ruling or drag, and it enabled internal fuel to reach 2,800 litres (616gal). The increased weight of spine fuel and the centreline pod forced the designers to restress the airframe for a limiting load factor of 6. This, and the q-pressure limitation of the sensor pods, resulted in maximum permitted speed and altitude being limited to the values given in the data (these limits did not apply to the clean aircraft).

In service the MiG-21R was commonly seen with a centreline pod, 490lit tanks on the outer pylons and the inner (original) pylons removed. In a war situation the inners would have been refitted, to carry R-3S missiles. Though the GP-9 gun pod could be carried, this could only have been at the expense of leaving the reconnaissance pod behind. From 1969 many aircraft were retrofitted with a TS-27AMSh rear-view periscope (zig-zag mirror) in the top of the canopy. The ASCC name was 'Fishbed-H'.

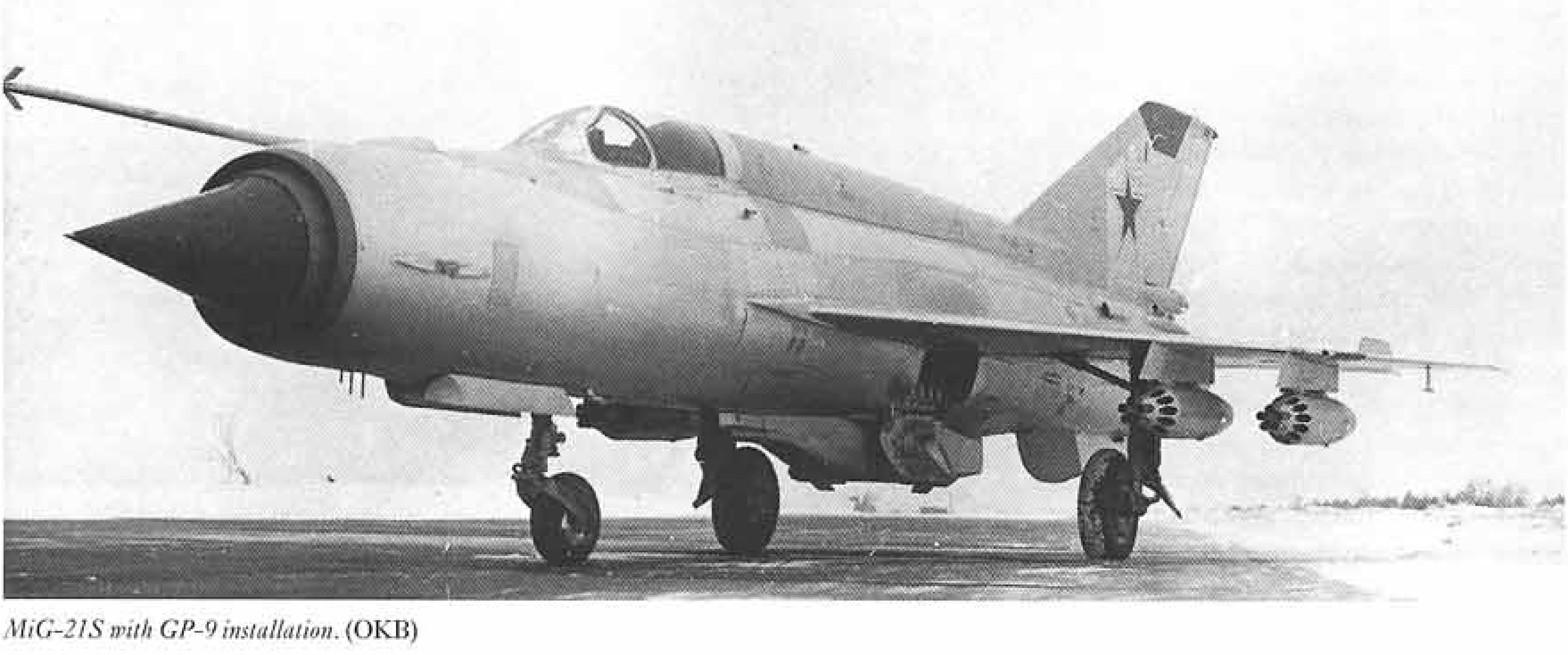
Dimensions unchanged.

Weight empty 5,696kg (12,557lb); internal fuel 2,296kg (5,062lb); weight loaded 8,100kg (17,857lb); maximum takeoff weight 9,200kg (20,282lb).

Maximum speed 1,150km/h (715mph) at sea level, 1,700km/h (1,956mph, Mach 1.6) at 13,000m (42,651ft); climb to 14,600m (47,900ft) 8.5min; service ceiling 15,100m (49,540ft); range (pod and two tanks) 1,600km (994 miles), (pod and four tanks) 2,000km (1,242 miles); takeoff run 900m (2,953ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).

MiG-21S, 95

The success of the Type 94 prompted the OKB to produce an improved frontal fighter *Izdeliye* 95. This was based on the 94, but with the structure once again cleared to a load factor of



MiG-21S with GP-9 installation. (OKB)

8.5. It combined the F2S engine, blown flaps, new seat and canopy, large spine with two 170lit tanks, very broad fin with large cap antenna, cruciform parabrake, AOA transmitter, gun pack and five pylons, with an upgraded radar, the RP-22 *Sapfir*. The offset air-data boom was of the new PVD-7 type, with a ram inlet, three rows of static apertures and weathercock vanes for AOA and sideslip/yaw. This was connected via the *Pion*-N (peony) feeder coupler to the optical sight and various subsystems, but the cockpit instruments were served mainly by the small auxiliary pitot near the windscreen and the AOA sensor on the left of the nose.

Developed by the Volkov KB, the new radar fitted into the existing compartments and nosecone but had greater emitter power, increasing range against the standard 16sq m (172sq ft) target to 30km (18.6 miles), with a tail-on pursuit range of 15km (9.3 miles). This radar was fitted in 1964 to prototypes designated Ye-7S (from *Sapfir*). A large order for Frontal Aviation was placed in the same year, and the production aircraft, designated MiG-21S, was produced at Gork'iy in 1965–68. In the course of production the TS-27AMSh rear-view periscope was added.

The better radar and extra pair of pylons greatly increased capability, but at the expense of continued degradation in performance. Compared with the initial production MiG-21F, normal loaded weight had increased by some 1.5 tons, with little change in engine power. Despite the substantial increase in internal fuel, rearward shift in the centre of gravity made it impossible to use all of this fuel safely, with the result that the range without drop tanks had actually decreased. The ASCC name remained 'Fishbed-H'.

Dimensions unchanged.

Weight empty 5,650kg (12,456lb); internal fuel 2,320kg (5,115lb); weight loaded 8,150kg (17,967lb); maximum takeoff weight 9,100kg (20,062lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,230km/h (1,386mph, Mach 2.1) at 13,000m; climb to 17,500m (57,415ft) 8.5min; service ceiling 17,900m (58,727ft); range 1,240km (771 miles), (800lit tank) 1,600km (994 miles); takeoff run 900m (2,953ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).

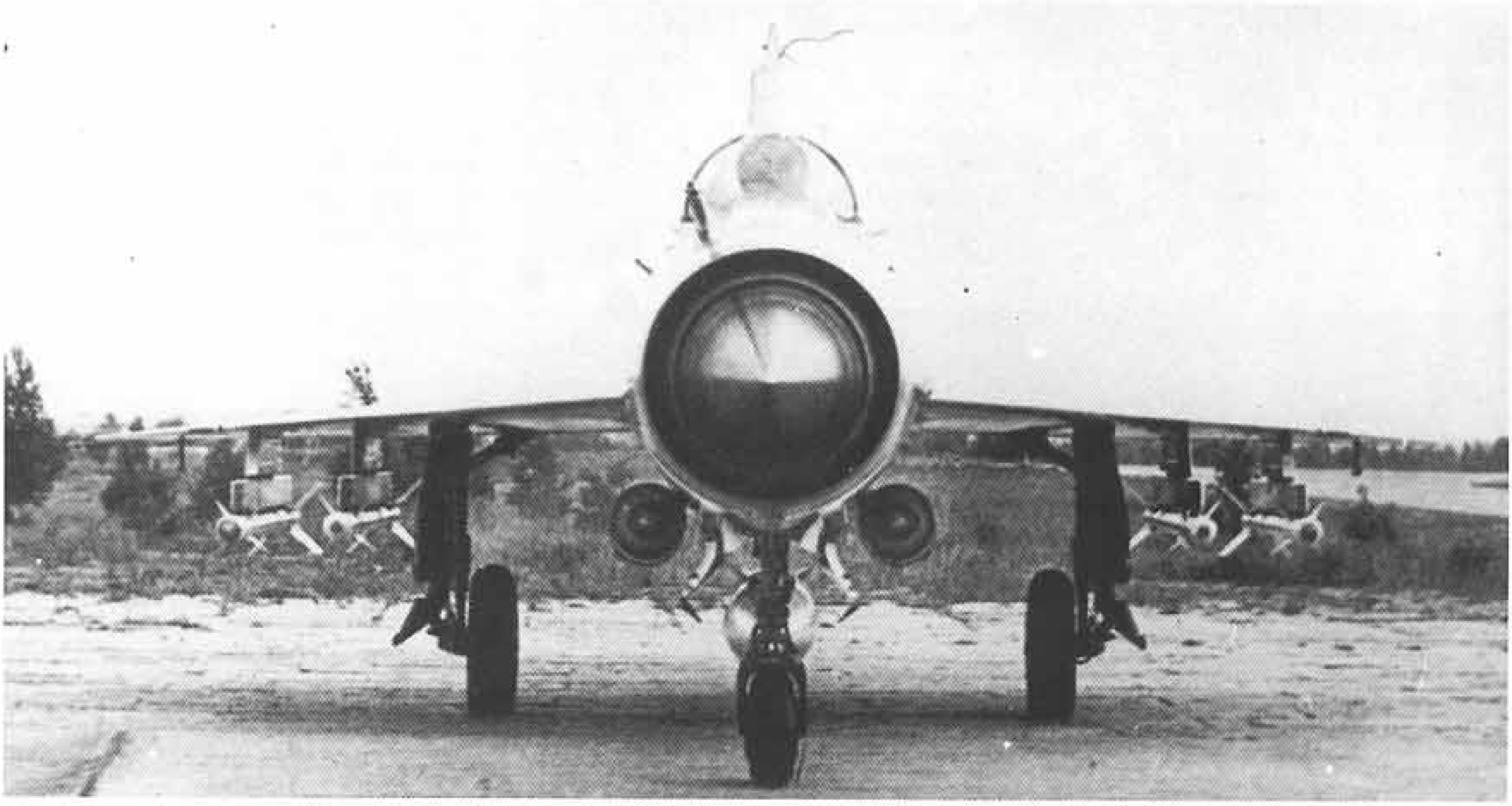
Ye-7N

With this designation a small number of development aircraft tested the carriage and release of tactical nuclear weapons. Special subsystems were installed to keep safe and finally arm these weapons, which in the standard form were carried in a streamlined container under the centreline.

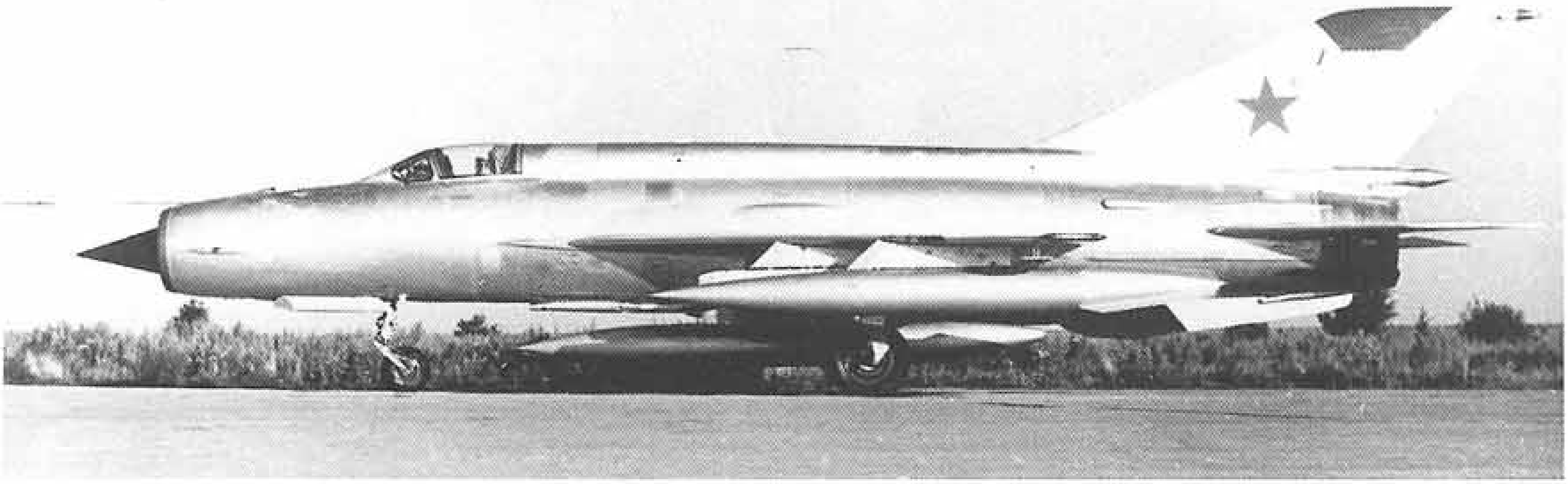
MiG-21SM, 95M, 15

Developed for Frontal Aviation, this was basically the 95 (MiG-21S) with a more powerful engine. In 1962 Sergei Alekseyevich Gavrilov opened his own OKB at Rybinsk/Ufa to develop improved versions of the R-11. The resulting R-13-300 (*see* Appendix 1) was qualified in 1966 at 4,070kg (8,973lb) thrust dry and 6,600kg (14,550lb) with maximum afterburner, but in the MiG-21 the top rating was listed as 6,490kg (14,308lb). Mikoyan first used the R-13 in the 23-31 described later. In the MiG-21SM few changes were needed to accommodate it, the inlet and duct being adequate and the engine mountings and pipe connections being deliberately made identical with the R-11F2S-300.

An important further modification was the installation of a GSh-23L gun, similar to the GSh-23, internally. The gun had always been welcome, but the drag of the GP-9 pack had been considerable. The new installation housed everything except the twin barrels and slanting case ejector chutes inside the fuselage. The magazine occupied the bay outboard of the air duct between Frames 13 and 14, the belt of 200 (maximum 220) rounds being fed in through a door just below the spine fairing on the left side. A steel blast panel was added to the fuselage skin just ahead of the muzzles. At low airspeeds and consequent high AOA, muzzle blast could blow open the auxiliary inlet doors and cause violent compressor stalls, so a small deflector strake was added immedi-



MiG-21SM with four K-13 and assisted-takeoff rockets. (Yefim Gordon archive)



MiG-21SM with three tanks. (OKB)

ately below each door. These also helped prevent ingestion of solid material during takeoff.

This gun installation freed the centreline pylon for a tank or other stores. Thus, it was now possible to fly with a gun and any combination of tanks, missiles, bombs or rockets on five pylons, three of them plumbed for tanks. The only other changes, compared with the MiG-21S, were minor changes in instrumentation. Thus, the *Izdeliye* number was originally 95M, but this was changed to the out-of-sequence number 15. In 1968–74 the number of this version produced for the Frontal Aviation, IA-PVO and A-VMF exceeded all other MiG-21 variants. As it did not change externally, the ASCC name remained 'Fishbed-H'.

Dimensions unchanged (some sources cite length excluding PVD as 14.185m, 46ft 6½in).

Weight empty 5,998kg (13,223lb); internal fuel 2,200kg (4,850lb); weight loaded 8,300kg (18,298lb); maximum takeoff weight 9,400kg (20,723lb).

Performance unchanged from MiG21S except climb to 17,500m (57,415ft) 9.0min.

MiG-21M

Broadly based on the 95, this export version was fitted with a previous-generation radar, the RP-21MA. This differed only in detail from the RP-21M, and was similarly used to provide guidance for the obsolescent RS-2US missile. Two of these could be carried, together with two other stores such as the self-homing R-3S missile. The sight was the upgraded ASP-PFD, and a completely new feature for export versions (first seen a year earlier on the MiG-21SM) was the semi-internal installation of a GSh-23L gun.

A large number of this version were built for export at the *Znamya Truda* factory in 1968–71. In 1971 the Indian government extended their manufacturing licence to include the Type 96, to which they allotted the designation Type 88. A total of 150 were built by HAL with assembly at Nasik between January 1973 and 1981. The ASCC name was 'Fishbed-J'.

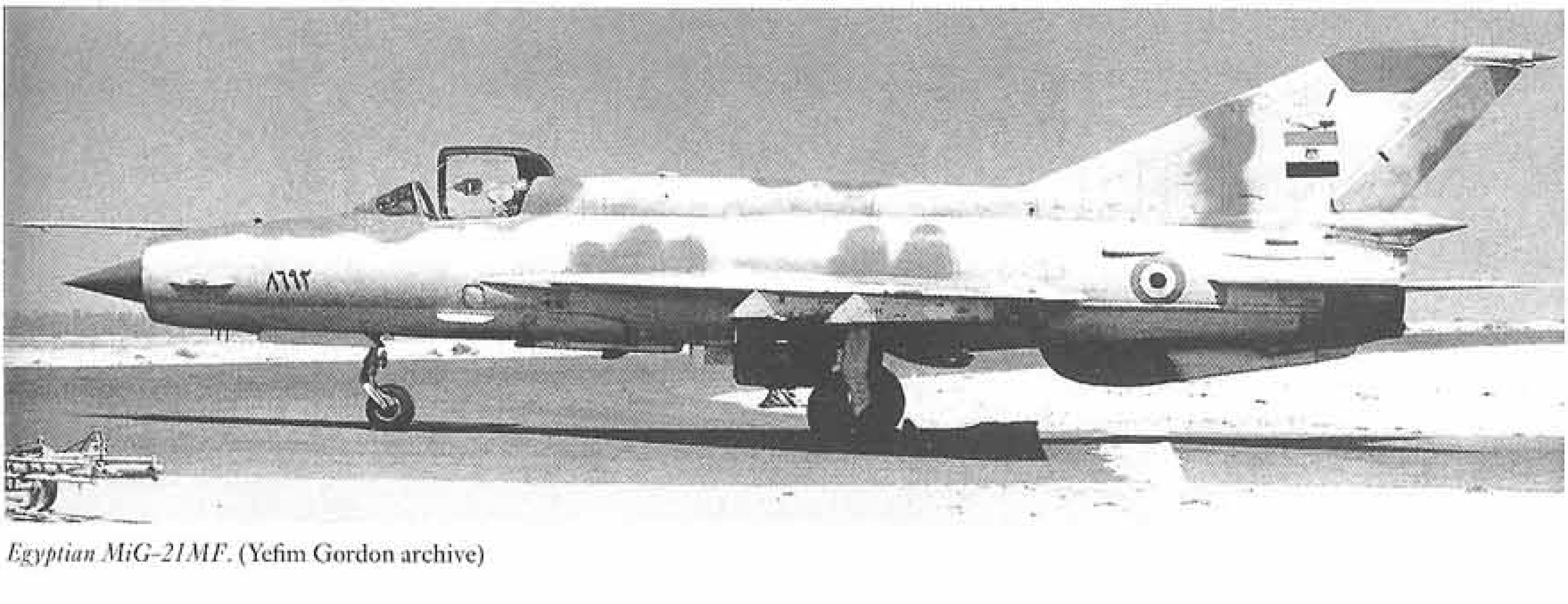
Dimensions unchanged.

Weight empty 5,950kg (13,117lb); internal fuel 2,200kg (4,850lb); weight loaded 8,950kg (19,731lb); maximum takeoff weight 9,400kg (20,723lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,230km/h (1,386mph, Mach 2.1) at 13,000m; climb to 16,800m (55,118ft) 9.0min; service ceiling 17,300m (56,760ft); range (internal fuel) 1,050km (652 miles), (3 tanks) 1,720km (1,069 miles); takeoff run 900m (2,953ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).

MiG-21MF, 96F

In all essentials this was an export version of the MiG-21SM, with the R-13-300 engine. Unlike the MiG-21M, a standard of avionics quite close to that of the MiG-21SM was permitted, the radar being the RP-22. Items not previously mentioned but standardized from 1964 included the RV-UM radar altimeter, and the integration of groups of equipment into systems called a *kompleks*, notably the SBU-23YeSN for flight control and the PNK Pilot-OI for navigation and bad-weather landing. Except for the first batch most aircraft were fitted with the TS-27AMSh periscope. OKB documents do not explain how, compared with the almost



Egyptian MiG-21MF. (Yefim Gordon archive)

Polish MiG-21MF. (Yefim Gordon archive)

identical MiG-21SM, the empty weight was 648kg (1,429lb) lighter.

The MiG-21MF was produced by the *Znamya Truda* factory between 1970 and 1974, and a further batch were produced at Gor'kiy in 1975. The ASCC name was 'Fishbed-J'

Dimensions unchanged.

Weight empty 5,350kg (11,795lb); internal fuel 2,200kg (4,850lb); weight loaded 8,212kg (18,104lb); maximum takeoff weight 9,661kg (21,299lb).

Performance unchanged except climb to 17,700m (58,071ft) 9.0min; range 1,050km (652 miles), (three 490lit tanks) 1,800km (1,118 miles).

MiG-21SMT, 50

In their ceaseless search for additional internal fuel capacity the MiG designers found that conformity with the area rule, and overall drag, would not be unduly affected by making the dorsal spine even larger. To give the required smooth curve of total drag from nose to tail the S and M families had a spine which slightly increased in cross-section to a maximum a short distance behind the cockpit. In 1969–70 a new spine was designed which swelled more boldly, to a grossly inflated maximum more than half-way from the cockpit to the fin, with its rear and faired into the parabrake tube. This was proposed for a new production version with the *Izdeliye* number 50, and Service designation MiG-21SMT (from SM plus *toplivo*, fuel).

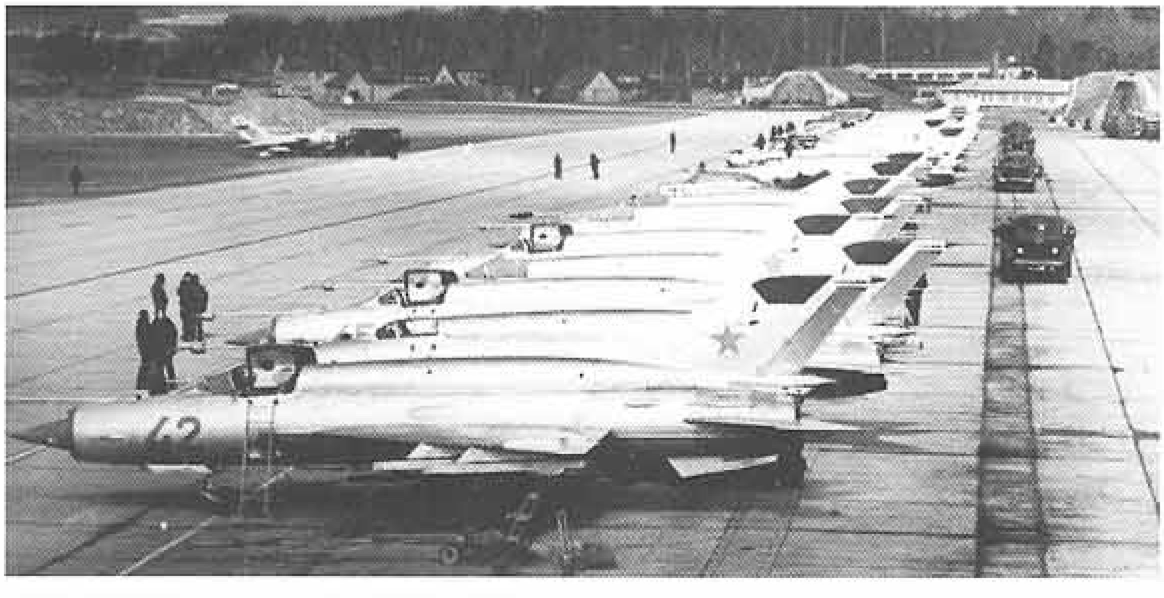
This very large spine was arranged to house a row of three saddle tanks with a total capacity of 900 litres (198gal), increasing total internal fuel to 3,250 litres (715gal). Inevitably, flight performance was reduced and takeoff run increased, but the OKB test pilots found the degraded in-flight stability margin no problem. However, it was eventually judged that the large mass of fuel well above the axis of rotation, and rearward migration of the centre of gravity, would make the proposed aircraft dangerous for inexperienced pilots, and it was decided to omit the rearmost spine tank. This reduced fuel capacity by 300 litres to 2,950 litres (649gal). In the long term this could be seen to be ironic, because with later flight-control systems fighters have been developed which are completely unstable longitudinally.

Clearly the result was a nonoptimized aircraft, and only a short batch of MiG-21SMT aircraft were produced by Gor'kiy in 1971–72. All were originally unpainted and sent to an Frontal Aviation regiment. Here they were later camouflaged, and most were soon modified to MiG-21ST standard. As delivered, the ASCC name was 'Fishbed-K'.

Dimensions unchanged.

Weight empty 5,700kg (12,566lb); internal fuel (test) 2,700kg (5,952lb), (production) 2,419kg (5,333lb); weight loaded 8,900kg (19,621lb); maximum takeoff weight 10,100kg (22,266lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,175km/h (1,352mph, Mach 2.04) at 13,000m (42,651ft); climb to 16,800m (55,118ft) 9min; service ceiling 17,300m (56,760ft); range 1,300km (808 miles), (800lit tank) 1,670km (1,038 miles); takeoff run 950m (3,120ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).



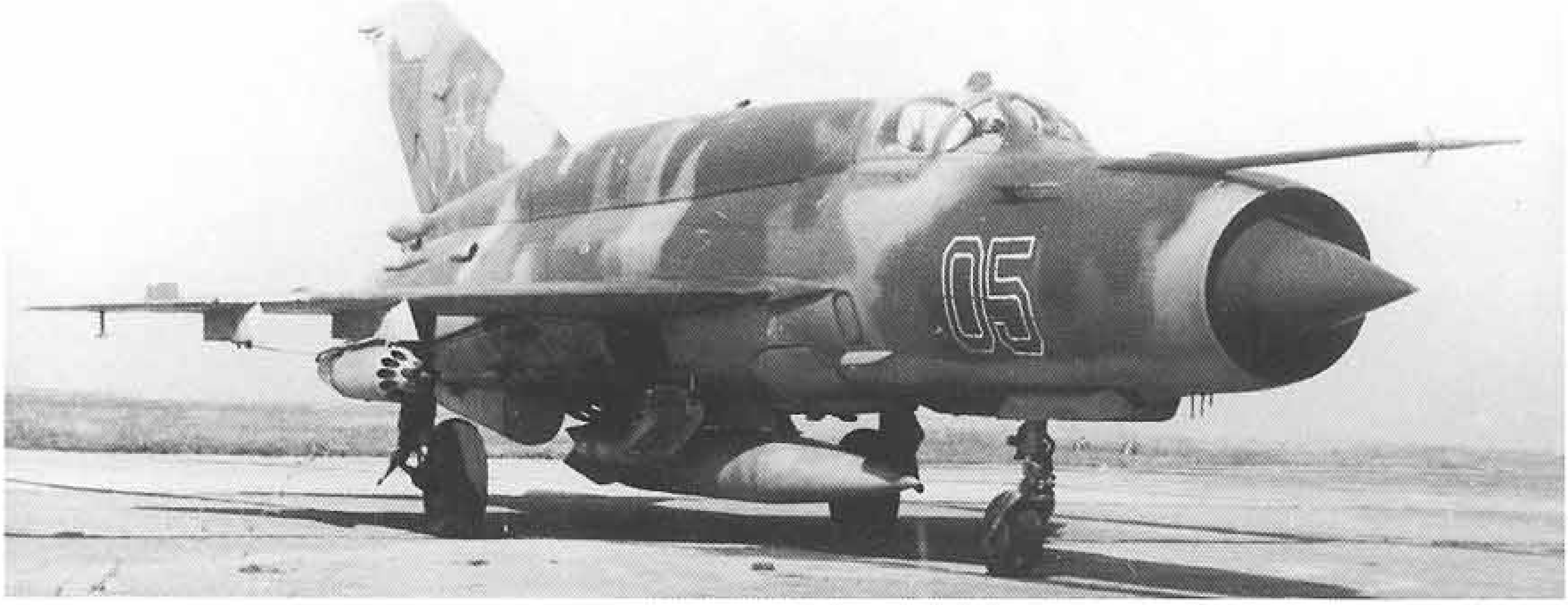
MiG-21SMT batch newly built. (RART/GP)

MiG-21MT, 96T

Intended as the export version of the MiG-21SMT, fifteen of this type were constructed at the *Znamya Truda* factory in 1971. Armament and radar were similar to those of the MiG-21MF. These aircraft were not exported; instead five went to the VVS test-pilot school and one was used as a research and trials aircraft by the MiG OKB.

MiG-21ST

In the early 1970s surviving MiG-21SMT aircraft were returned to workshops and modified with a smaller spine. Instead of merging into



MiG-21SMT at NII-VVS. (Yefim Gordon archive)

the parabrake tube this tapered off into the fin. In shape it was intermediate between the almost constant-section spine of the S and M versions and the grossly swollen spine fitted originally, and it was externally almost identical to that of the later MiG-21bis. Fuel capacity remained 2,950 litres (649gal).

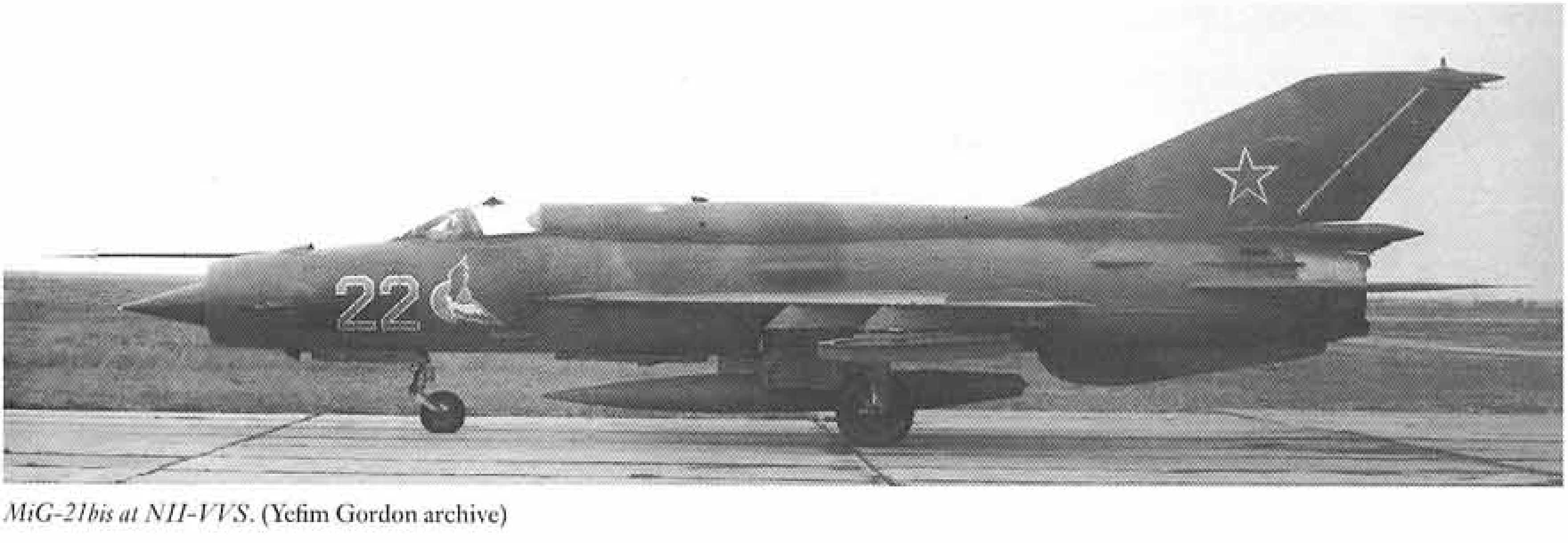
MiG-21bis, 75, 75A, 75B

In February 1971 the OKB began a detailed study of every aspect of what had become its most successful product, to optimize its design to keep abreast of new challenges. It was spurred to do this by availability of yet another upgrade of the original Tumanskiy engine. This was the R-25-300, again produced by Gavrilov's bureau. Though installationally interchangeable with the R-13, it introduced numerous further improvements, particularly to the afterburner, to give dry and maximum afterburning ratings of 4,100kg (9,039lb) and 7,100kg (15,653lb), respectively. This was more than double the power of the first MiG-21 prototypes.

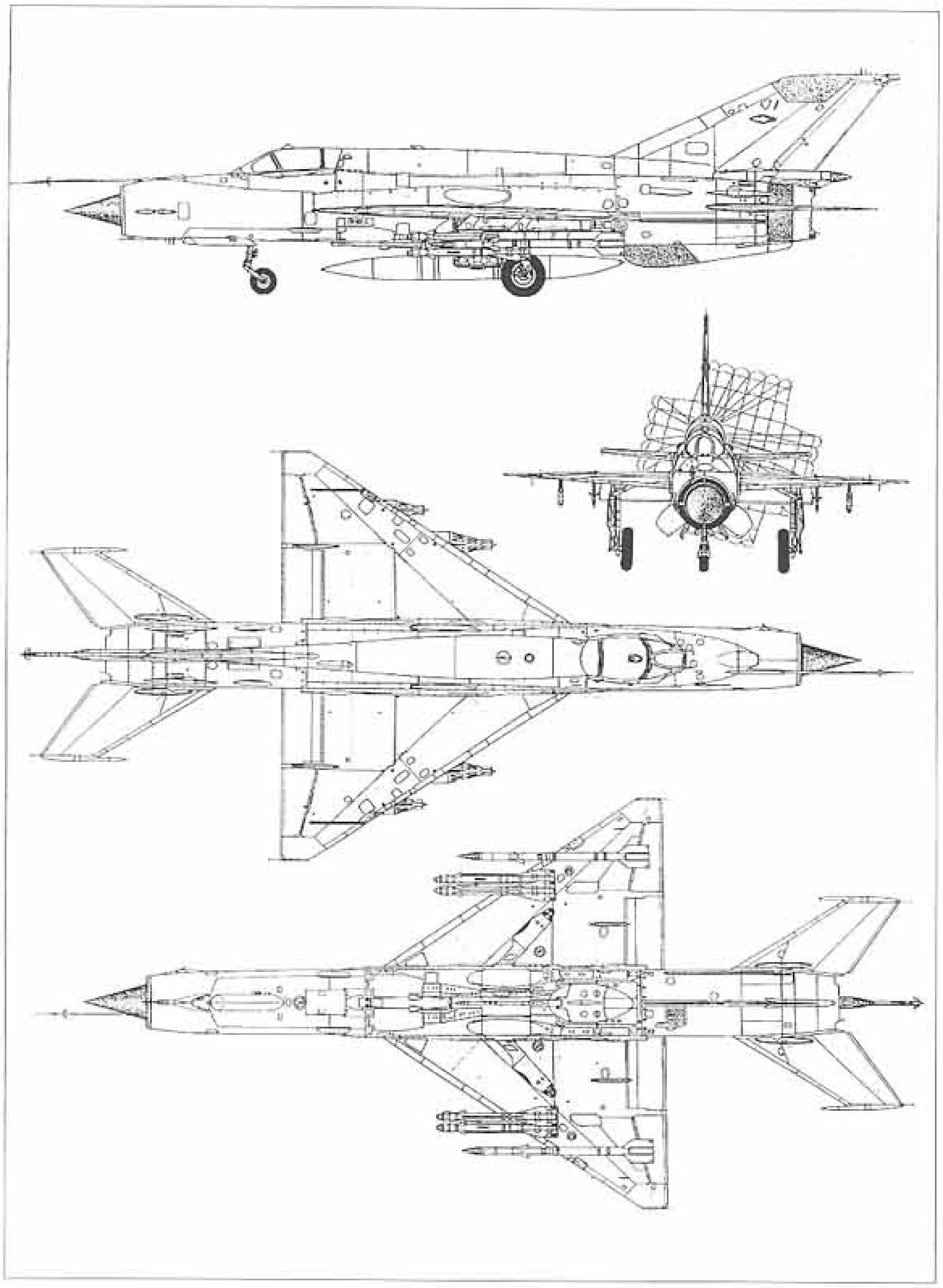
Over seventeen years the MiG-21 airframe had been modified and locally strengthened so often that it had become increasingly far from the optimum. The new fighter, *Izdeliye* 75, was given an ideal modern structure, again stressed to a load factor of 8.5 and made from the latest alloys of aluminium and titanium offering greater strength and fatigue life. None of this showed externally, except that the spine was slightly larger than that of the S and M versions, but nothing like as capacious as that of the SMT.

Armament was upgraded to include the GSh-23L gun and all previous rocket/bomb combinations, as well as the R-3R, R-3S and the new R-3M missiles, as well as the very agile R-60 and R-60M dogfight missiles. A few training missions were flown with the R-55, which was the old RS-2US with an IR-homing head. The ASP-5ND sight was modified to aim accurately in manoeuvres at up to 2.9g.

The radar remained the RP-22 but with improved discrimination looking down against targets near the ground. An important upgrade was the RSBN-5S or -6S navigation system, which over short ranges was extremely accurate. It was served by horizontal rod antennas under the nose and above the tail. A standard fit was automatic monitoring and recording for the engine and parts of the airframe to facilitate maintenance. Some aircraft, including those for export, had SRO-2 IFF, while others had SRZO-2 with blade instead of rod antennas. Some were fitted with the *Lazur* receiver, and were designated MiG-21bisLazur. Others were fitted with the SAU-21 autopilot. The *Izdeliye* numbers of series aircraft were 75A for Warsaw Pact recipients and 75B for export customers.



MiG-21bis at NII-VVS. (Yefim Gordon archive)



MiG-21bis (with two R-3R or R-3S and four R-60), parabrake in front elevation.

Soviet production of MiG-21bis fighters took place only at Gor'kiy, where 2,030 were made in 1972–74. In addition, 220 were initially assembled and ultimately manufactured by HAL Nasik division for the Indian Air Force in 1979–87. Overall production totals for the MiG-21 follow the entries for the trainer versions. The ASCC name for the MiG-21bis was 'Fishbed-L' for a version erroneously thought to have the R-13-300 engine, and 'Fishbed-N', with the R-25 engine. These names were later changed to identify versions without and with the RSBN antennas.

Dimensions unchanged.

Weight empty 5,895kg (12,966lb); internal fuel 2,390kg (5,269lb); weight loaded 8,725kg (19,235lb); maximum takeoff weight 10,420kg (22,972lb).

Maximum speed 1,300km/h (808mph) at sea level, 2,175km/h (1,352mph, Mach 2.04) at 13,000m (42,651ft); climb to 17,000m (55,774ft) 8.5min; service ceiling 17,800m (58,400ft); range 1,225km (761 miles), (two R-3S and 800lit tank) 1,470km (913 miles); takeoff run 830m (2,725ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).

MiG-21K

This designation identified 'Red 44', a testbed for new equipment. It was exhibited at Khodynka in 1989.

MiG-21U, 66, Ye-6U

In 1958 there were dual-control trainer versions of all the latest Sukhoi and Yakovlev jets either in service or under development, but the only MiG trainer was the UTI MiG-15, of an earlier generation. Accordingly, Mikoyan asked his team to study a trainer version of the MiG-21, which as a Mach-2 aircraft with a highly loaded delta wing posed new problems to pupil pilots.

The trainer went into engineering design in November 1959, as *Izdeliye* 66. Service designation was MiG-21U (*uchebnyi*, trainer). To a remarkable degree it was identical to the MiG-21F-13, and design load factor remained 7.0. Apart from moving the air-data boom to the top of the nose, almost all the changes were confined to the fuselage between Frames 6 and 22.

Following universal Soviet practice, the pupil sat in front, in what had been the original cockpit. To add the instructor cockpit the section between Frames 12 and 22 was completely redesigned. The NR-30 gun and its magazine were removed. It was decided that, should a gun be needed, an A-12.7 heavy machine-gun, with magazine and control system, should be packaged in a pod and carried on the centreline pylon. The twin forward airbrakes were replaced by a single airbrake on the centreline, which was just as effective. These changes made it possible to install a new aluminium Tank 1 filling the space between the ducts between Frames 14 and 22, extending up into the new canopy fairing. Thus, instead of fuel capacity being reduced, it was actually increased over that in the first MiG-21 fighters, to 2,350 litres (517gal).

Both cockpits were very similar to that of the MiG-21F-13, and the seats remained SK type. No attempt was made to raise the instructor above the level of the pupil to improve his forward view. As it was no longer possible to use the canopy as a windbreak, the trainer was given a conventional windscreen (not quite the same as that on later MiG-21 fighters) and separate canopies over the two cockpits, each hinged to starboard. In the production trainer each canopy could be locked open by a stay at the front. A flat transparent panel between the cockpits carried the pressure seals for the adjacent edges of the canopies and served as a windbreak in the event of loss of the rear canopy, but it was not stressed to serve as a crash arch.

Provision for a tank, rocket pod, K-13, (R-3S) missile or bomb under each wing was retained. Because of the frequency of landings, the mainwheels were of the type introduced with the MiG-21P interceptor, with an 800mm (31.5in) tyre, necessitating larger blisters above and below the wing. Equipment included the ASP-5ND sight with SRD-5 ranging radar, KAP-2K autopilot, SRO *Khrom* IFF with lower-hemisphere antenna immediately behind the nosewheel, and parabrake in the underside of the fuselage.

Hardly any problems were encountered, and the trainer prototype, designated Ye-6U/1, callsign 'Red 61', was first flown by Ostapenko on 17 October 1960. It was soon joined by the Ye-6U/2, with a telemetry antenna under the forward fuselage. Factory testing took nine months, overlapped with NII-VVS testing. A large order was quickly placed, but to fulfil this fresh production capacity had to be found. The choice fell on former Factory No. 31, at Tbilisi, Georgia. Production began here in 1962, and 180 MiG-21U trainers were delivered by 1966, when the assembly line switched to the MiG-21US. Export trainers were manufactured at the *Znamya Truda* factory, in 1964–68. Early in production the fin was changed to the very broad pattern that had been standardized on the fighters, with the parabrake above the jetpipe, and later the mainwheels were changed to the KT-102 type with disc brakes.

Dubbed *Sparka* (twin), the trainer was immediately popular. Performance and handling resembled those of the MiG-21F-13. In 1965 a prototype was fitted with an uprated engine and used to set women's altitude records. On 22 May Nataliya Prokhanova made a zoom to 24,336m (79,843ft), and on 23 June Lidiya Zaitseva held a sustained altitude of 19,020m (62,402ft), well above the brochure service ceiling. The aircraft was reported to the FAI as the 'Ye-33'. The ASCC decided to call the trainer 'Mongol'.

Dimensions unchanged.

Weight empty 5,195kg (11,453lb); internal fuel 1,950kg (4,299lb); weight loaded 7,800kg (17,196lb).

Maximum speed 1,150km/h (715mph) at sea level, 2,175km/h (1,352mph, Mach 2.04) at 13,000m (42,651ft); climb to 17,800m (58,399ft) 8min; service ceiling 18,300m (60,040ft); range 1,220km (758 miles), (490lit tank) 1,420km (882 miles); takeoff run 900m (2,953ft); landing speed 280km/h (174mph); landing run 800m (2,625ft).

MiG-21US, 68, Ye-6US

As its designation implied, this was the MiG-21U fitted with blown flaps. The latter were identical to those of the fighters, supplied with air from the R-11F2S-300 engine. The MiG-21US was later used to train pilots in landing with flaps at 45° with blowing.

A further modification was to fit an improved crew-escape system. The pupil was seated in a KM-1U seat, while the instructor had a KM-1I, both being versions of the SK-3. Like other versions, both could be used at any height down to ground level, provided airspeed was not below 130km/h (81mph). Each cockpit had a lever on the right-hand coaming which initiated an automatic sequence by blowing off the canopies and arming the seats. The only limitation was that the instructor's seat could not be ejected by the pupil.

Among other modifications were provision for four pylons and an increase in internal fuel capacity to 2,450 litres (539gal). Another improvement, for which instructors had clamoured, was to fit the rear canopy with a periscope. The view ahead was even worse than from the single-seaters, and the new periscope was unfolded automatically by extending the landing gear. It had zig-zag optics which, unlike the TS-27AMSh of the fighters, gave a view ahead, not astern.

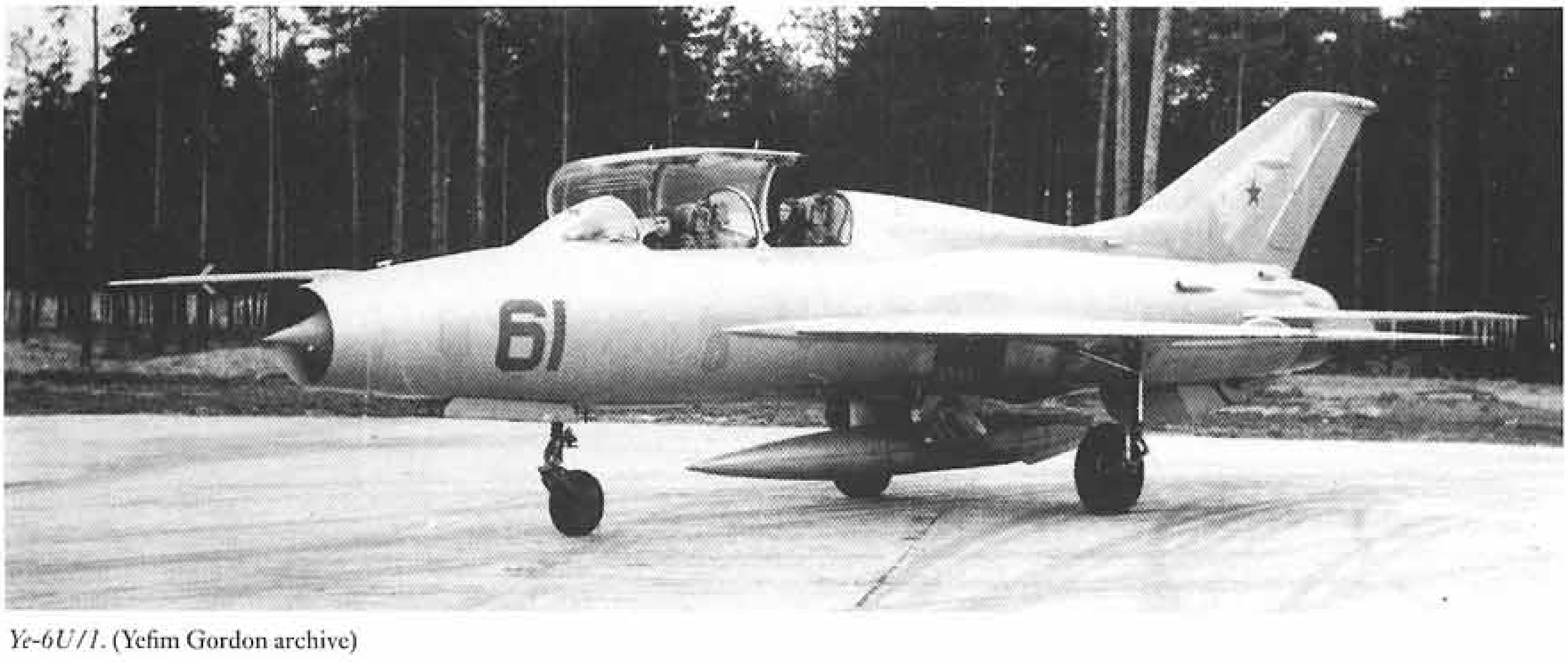
All these modifications were developed with the Ye-6US prototype. In 1974 this aircraft was used by Savitskaya to set time-to-height records. On 6 June she reached 3,000, 6,000, 9,000 and 12,000m in 59.1sec, 1 min 20.4sec, 1min 46.7sec and 2min 35.1sec, respectively. These figures were reported to the FAI as having been gained by the 'Ye-33'. On 15 November she took off with two SPRD-99 rockets, jettisoned at burnout, and passed the same altitudes in 41.2sec, 60.1sec, 81sec and 1min 59.3sec, respectively. This time the aircraft was called the 'Ye-66B'.

Production of the MiG-21US took place only at Tbilisi. This factory delivered 347, for Soviet and foreign customers, in 1966–70. The ASCC name was 'Mongol-B'.

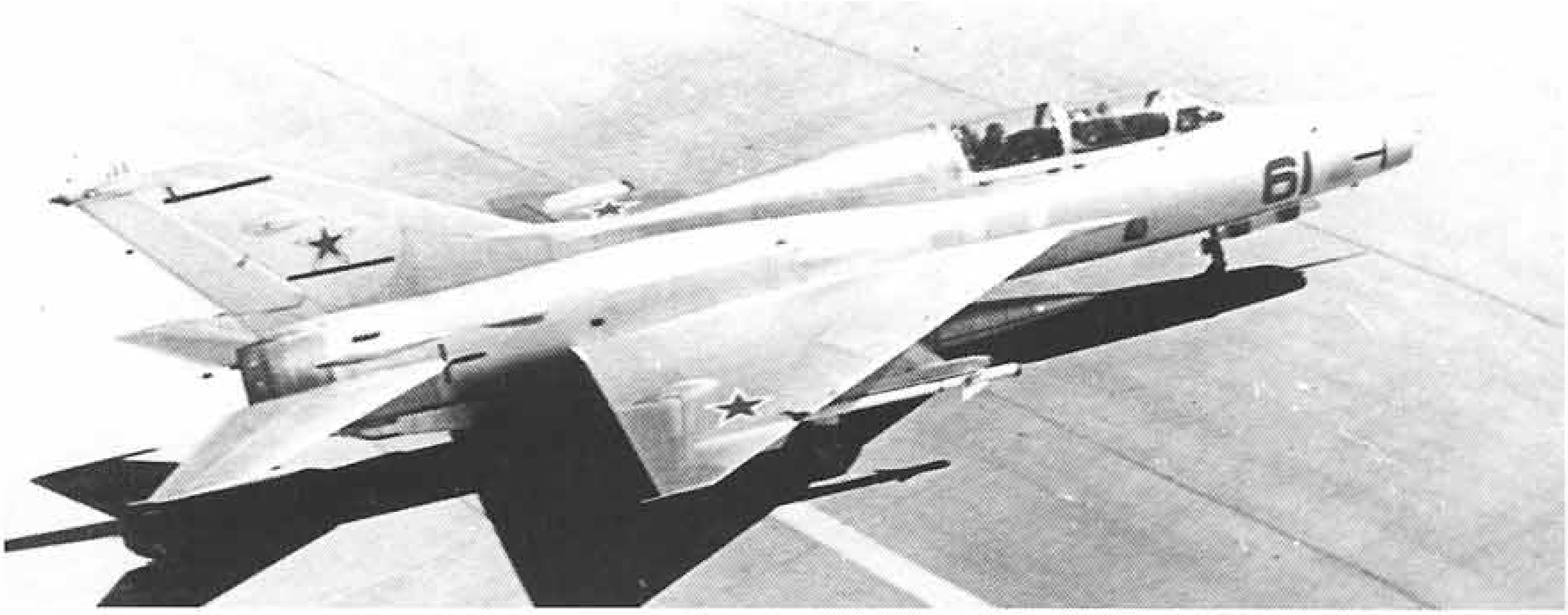
Dimensions unchanged.

Weight empty 5,380kg (11,861lb); internal fuel 2,030kg (4,475lb); weight loaded 8,000kg (17,637lb).

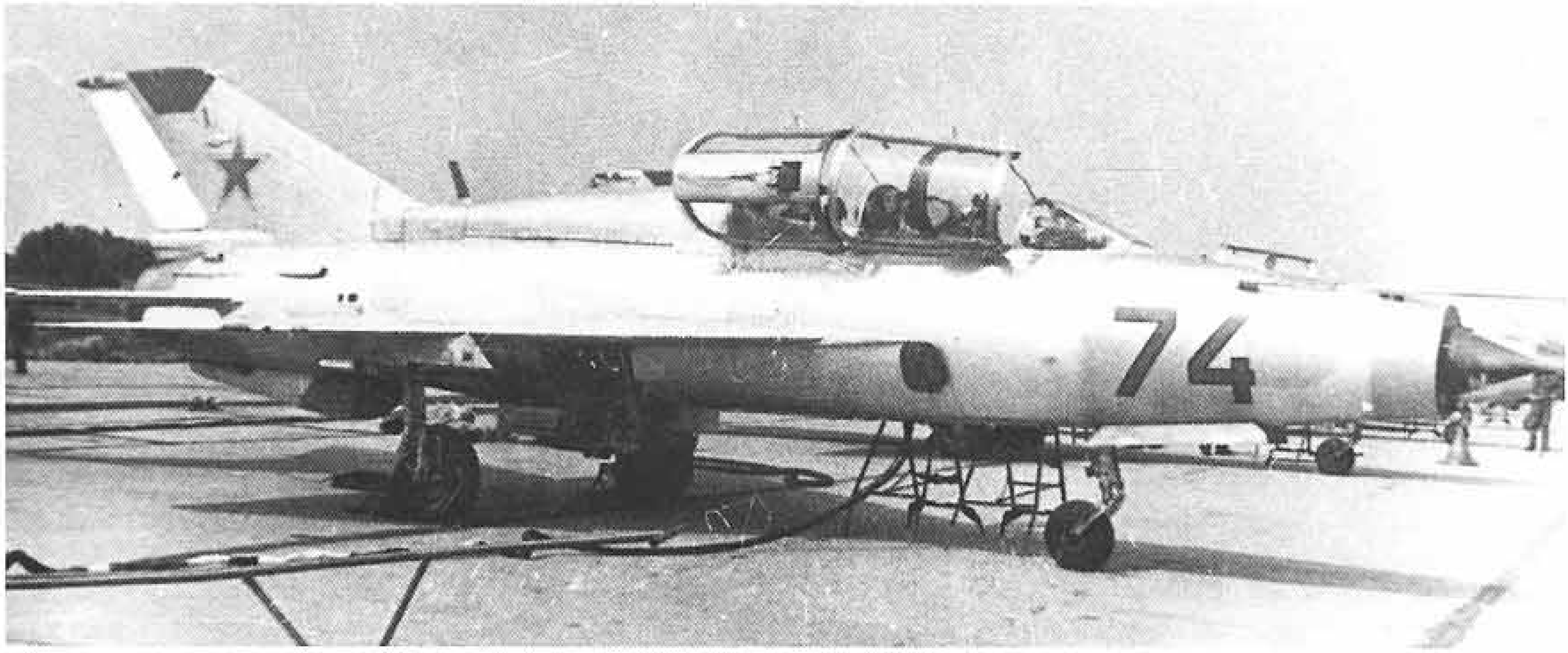
Maximum speed 1,150km/h (715mph) at sea level, 2,175km/h (1,352mph, Mach 2.04) at 13,000m (42,651ft); climb to 17,200m (56,430ft) 8min; service ceiling 17,700m (58,070ft); range 1,210km (752 miles), (490lit tank) 1,450km (901 miles); takeoff run 900m (2,953ft); landing speed 250km/h (155mph); landing run 550m (1,804ft).



Ye-6U/1. (Yefim Gordon archive)



Ye-6U/1. (Yefim Gordon archive)



MiG-21UM. (Yefim Gordon archive)

MiG-21UM, 69

The final type of trainer differed only in its standard of equipment. The most important upgrades were to fit the AP-155 three-axis autopilot and the DUA-3A AOA sensor on the left side of the nose. Other additions included the ASP-PFD computerized sight and R-832 vhf/uhf radio with a blade antenna just ahead of the fin. This version was produced at Tbilisi for Soviet and foreign customers from 1971, the last Soviet-built MiG-21 coming off the line in April 1975. The ASCC name was again 'Mongol-B'.

Dimensions and weights unchanged.

Performance unchanged, though some documents cite inferior climb to only 16,800m (55,118ft) in 8 minutes, and service ceiling of only 17,300m (56,760ft).

MiG-21 target conversions

Since the mid-1960s there have been several programmes to convert MiG-21s into various kinds of unmanned aircraft. The most important is the M-21. Named *Mishen*' (target), the M-21 is an official programme by the MiG bureau (later A I Mikoyan OKB, now MAPO-MiG) in partnership with the Kazan Aeronautical Institute (KAI).

So far all M-21 conversions have been based on the MiG-21PF or PFM, but similar conversions have been designed for both earlier and later versions. The prototype, callsign '01', was a PF with the seat replaced by command radio receivers, the radar replaced by ballast, the autopilot connected into the new radio-command system to drive the surface power units, and suitable command radio receiver antennas added. The most prominent of the latter were spiral planar domes looking like truncated cones ahead of and behind the nose landing gear, and a pod facing to front and rear above the fin. Additional small pylon-like structures were added on each side of the rear fuselage beside the parabrake tube, and the underside of the nose was sprinkled by a 'farm' of blade antennas.

Surprisingly, the only production M-21 to have been examined at close quarters – callsign '03' painted in thin red outline at the NII-VVS at Akthubinsk – was a modified MiG-21PFM which retained its seat and rear-view periscope. It also lacked the fin pod and the blade antennas on the nose. The number of conversions is expected to be about one hundred, some of which may be to a different standard designated **MiG-21Ye**. Both versions retain full

7.8 or 8.5g manoeuvre capability, either remotely piloted or following a preprogrammed trajectory, but they are limited to subsonic speeds.

In early 1996 the US electronics company Tracor offered a drone conversion of the MiG-21 designated QMiG-21. The company had at that time acquired five MiG-21Rs and a MiG-21UM, and two conversions were in hand. One of the possible customers with which Tracor was in negotiation was reported to be the United Kingdom, the others being in the Far East.

MiG-21-93

Today OKB-155 is part of the MAPO-MiG group, and the former Factory No. 31 at Gor'kiy is called the *Sokol* (falcon) production enterprise in the city whose name has been restored to Nizhniy-Novgorod. Both are urgently looking out for business, and whilst naturally preferring to sell new aircraft the MiG management consider that they ought to be the leaders in updating the still considerable worldwide population of MiG-21s.

With the collapse of the Soviet Union in 1990–91, support for these aircraft vanished. Existing contracts were null and void, and no new contracts could be entered into. First off the mark were the Israelis, discussed later.

Today MAPO-MiG are understandably irritated at the way foreign competitors, notably in China, Israel and Romania, are trying with some success to do business with the aircraft created by the MiG OKB. In the field of upgrades, co-author Gunston was asked by Rostislav Belyakov 'How can anyone offer a MiG-21 update without the cooperation of the designers?', while lead designer Sergei Budkevich said 'Nobody can rival the service we can offer. Our team includes Fazotron for radars and Vympel for world-beating missiles'.

The MiG-21-93 is a carefully designed remanufacture of the MiG-21bis (earlier versions could be handled, but at a higher price). The designation reflects the year the prototype was first displayed, at the factory in Nizhniy-Novgorod. Very loosely the upgrade packages the avionics and weapons of the MiG-29 or 33 into the smaller aircraft. At customer request the engine could also be changed to the MiG-29's RD-33 or the Russo-South African SMR-95.

Originally it was proposed to replace the radar by the Fazotron *Kop'yo* (spear). This is similar in size to the RP-22 *Sapfir* it replaces, in having an installed volume of 0.5cu m (17.7cu ft) and mass of 165kg (364lb) including the liquid-cooling system. Based on the N-010 *Zhuk* (beetle) of early MiG-29s, this was originally said to have a tail-on detection range of some 45km (28 miles); this was later upgraded to 57km (35.5 miles). It can look down at moving targets only 30m (100ft) above the Earth, and unlike the *Sapfir* family can track-while-scan eight targets and simultaneously lock-on to the two posing the greatest threat.

The first MiG-21-93 conversion began its factory test programme on 25 May 1995. Since then details have been discussed for upgrade of '120 plus options' for the Indian Air Force, with work shared between *Sokol* and HAL. In 1995 Fazotron offered the *Super Kop'yo*, with a range against front-hemisphere targets increased to 75km (46.6 miles). It comes with a new processor which, among other things, can count targets in a tight formation. The MiG-21-93 is also offered with an opto-electronic unit comprising an IR search/tracker combined with a laser for target ranging and directing air-to-surface missiles.

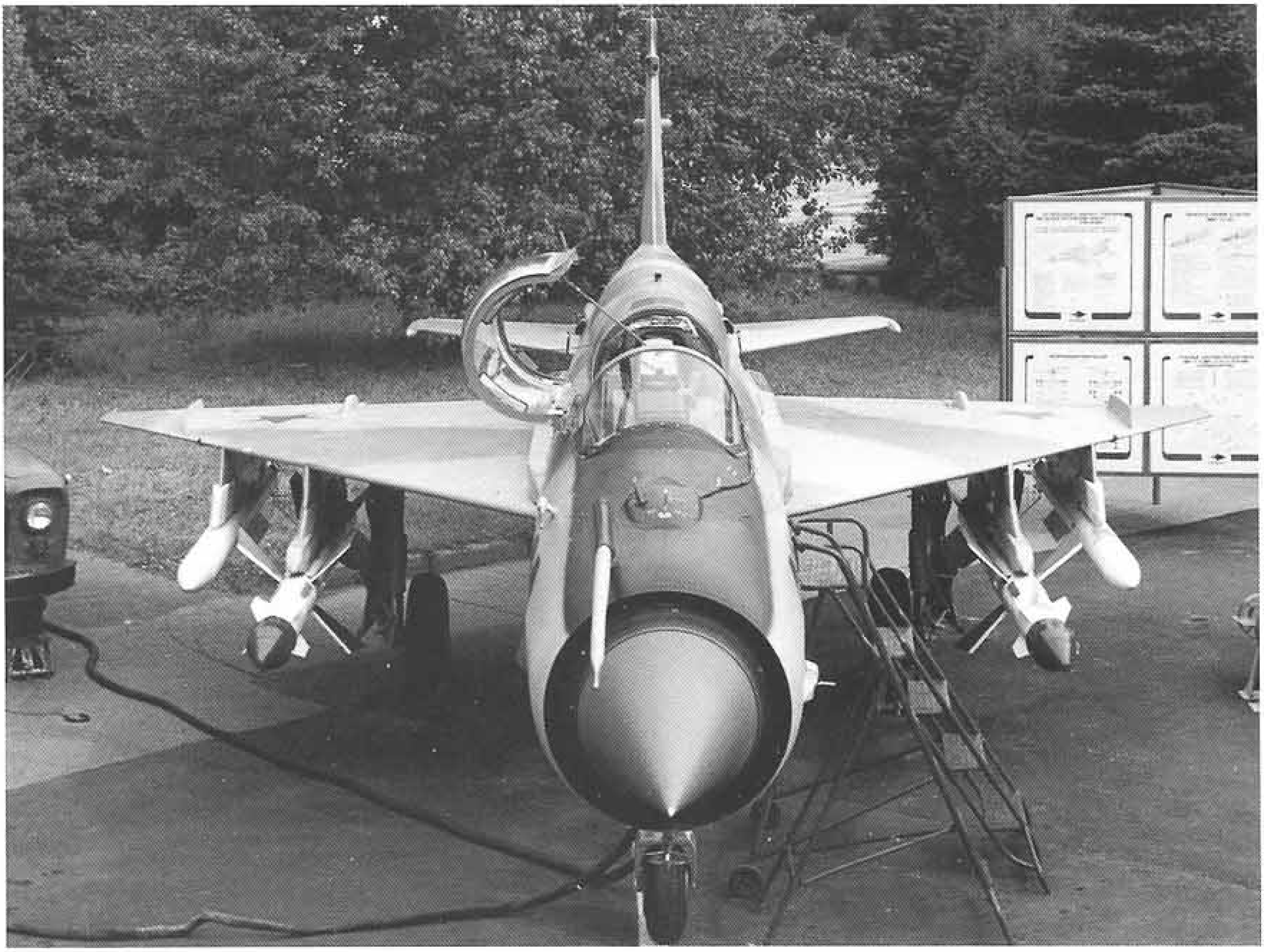
The missiles offered for the MiG-21-93 comprise the R-60M, R-60MK, R-27R1, R-27T1, R-73E and R-77 for air-to-air use, and the Kh-25MP, Kh-31A, Kh-31P and Kh-35 for use against surface or ship targets, as well as various 'smart' bombs such as the TV-guided KAB-500KR (*see* Appendix 2).

MiG-21-2000

For over thirty years Israel Aircraft Industries (IAI) have toiled to make themselves one of the foremost, if not *the* foremost of the world's suppliers of combat-aircraft upgrades. They have long regarded the big MiG-21 market as a major target, and teamed with Aerostar of Romania to offer upgrades of a growing number of variants. Under the general designation MiG-21-2000 these upgrades are tailored to suit each customer.

The baseline MiG-21-2000 has few airframe changes apart from a structural audit and replacement of the windscreen by a screen of moulded polycarbonate giving unobstructed forward view and enhanced resistance to birdstrikes. The seat is replaced by a Martin-Baker Mk 10, the radar by an Elta EL/M-2032, and a very wide range of other new avionics is on offer, depending on customer demand. The radar has a look-up range up to 102km (63 miles) and look-down range out to 83km (51.6 miles), with advanced features including doppler beam sharpening. Other upgrades include

MiG-21-93. (Nizhniy-Novgorod plant)



MiG-21-93. (photograph by Viktor Drushlyakov)

increased internal fuel, various EW (electronic-warfare) pods and chaff/flare dispensers.

The first MiG-21-2000 began flight testing on 24 May 1995, one day ahead of the MiG-21-93. Talks have been held with many potential customers, and the key launch customer was from the outset Romania, but in 1997 the only announced customer was Cambodia.

23-31, 92

One of several research aircraft based on the MiG-21, this was one of three prototypes built by the MiG OKB in the mid-1960s to investigate methods by which fighter field length might be reduced (the others were the 23-01 and 23-11/1).

The 23-31, *Izdeliye* 92, was essentially a MiG-21PFM with the fuselage from Frame 12 back to the junction with the rear fuselage at Frame 28A completely redesigned to house two RD-36-35 lift jets, equally disposed ahead of and behind the centre of gravity. This engine (*see* Appendix 1) was a simple turbojet designed to give lift for short periods at takeoff or landing. Sea-level thrust was 2,350kg (5,181lb) each. They were not pivoted but fixed at an inclination of 80°, fed from the ordinary fuel tanks and started by turbine impingement jets fed by air bled from the main engine.

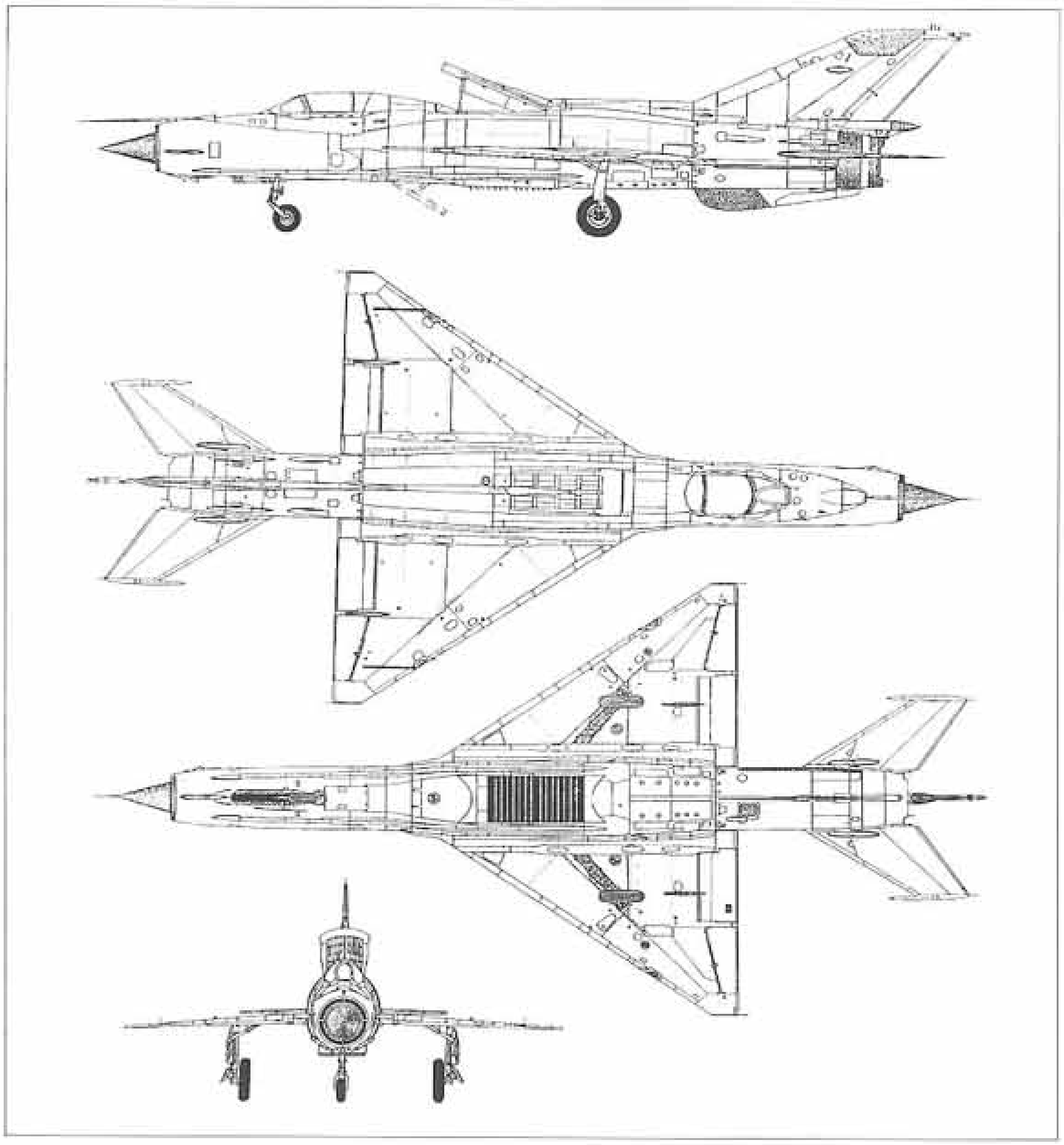
The lift-engine bay was considerably bulkier than the original fuselage section. Air for the lift engines was fed through a large louvred door forming the top of the centre fuselage, which in jet-lift flight was hinged at the rear and pushed up by a ram. Along the underside of the bay was a vectoring box, a rectangular frame containing transverse curved vanes, seven under each jet. Made of heat-resisting steel, these were pivoted and interlinked so that they could be vectored by the pilot through an angular range of some 50°, to give forward thrust or braking.

MiG-21 production

The following is a list of producers of the MiG-21:

	Fighters	Trainers	Total
Soviet Union			
Gor'kiy (Nizhniy-Novgorod)	5,278	–	5,278
Moscow (*Znamya Truda*)	?	?	3,203
Tbilisi	17	1,660	1,677
Czechoslovakia	194	–	194
India	657*	–	657*
China	?	?	2,400 (approx)
Total	6,146+	1,660+	13,409 (approx)

* Including assembly from Soviet-supplied parts, not counted twice.



23-31.

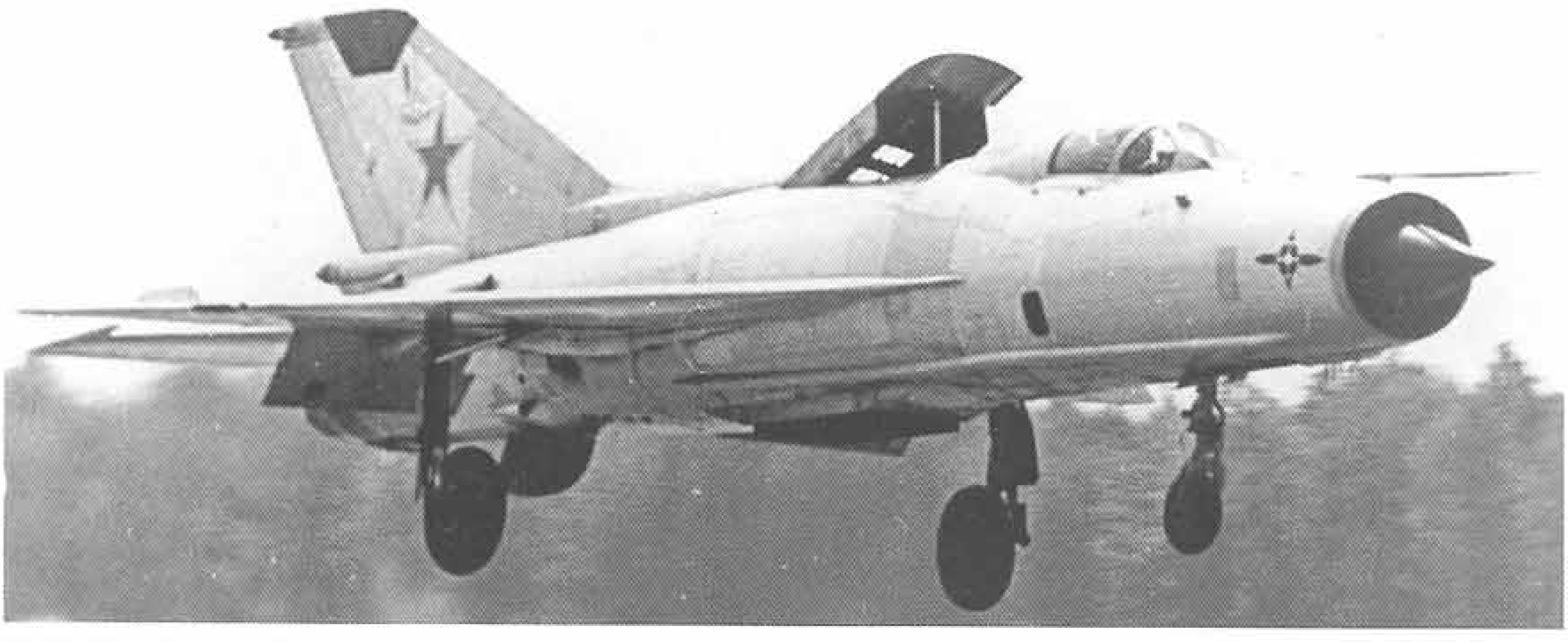
23-31. (Yefim Gordon archive)

No attempt was made to achieve a streamlined high-speed aircraft. Extra inboard wing sections were added, set at a positive angle of attack, which increased track from the standard 2.692m (8ft 10in) to 3.4m (11ft 1⅞in). Wheelbase was increased to 5.15m (16ft 10¾in). The lift-engine bay made it impossible for the main landing gear to retract, and the nose unit was also nonretractable, all wheel and leg bays being skinned over. Bleed air pipes from the main engine supplied reaction-control jets for use at low airspeeds. A nozzle pointed down under each wingtip, and a third under the nose, served by external pipes along each side of the fuselage. Only one airbrake was fitted, of a unique design ahead of the lift-jet bay. Under the nose were a drift sensor and telemetry antenna. Black/white kinetheodolite targets were painted on the left side of the nose and rear fuselage.

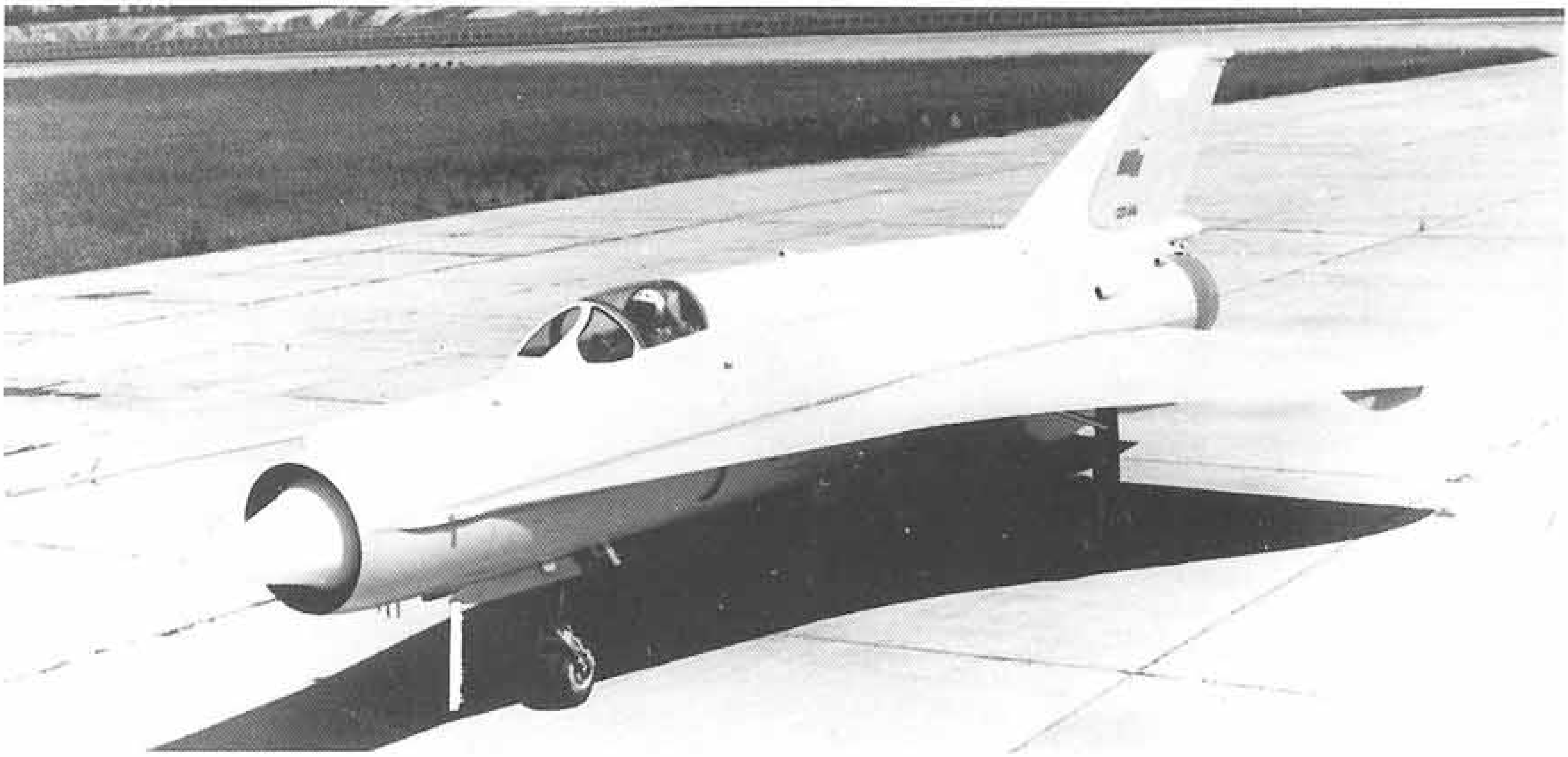
The 23-31 was first flown by Ostapenko on 16 June 1966. He found that 'For takeoff you need maximum dry power on the main engine, but for landing you need afterburner!' He shared factory testing with B A Orlov. The 23-31 was basically unstable at low airspeeds, and control was inadequate. It took part in a public display on 9 July 1967, and was then retired. The ASCC called it 'Fishbed-G'.

Span 7.765m (25ft 5¾in); length 14.72m (48ft 3½in), (fuselage, from inlet lip) 12.3m (40ft 4¼in); wing area 26.5sq m (285sq ft).

Maximum speed about 600km/h (373mph); minimum speed approx. 150km/h (93mph); range about 1,000km (620 miles); takeoff run about 300m (1,000ft); landing run about 100m (330ft). No other data.



23-31. (Yefim Gordon archive)



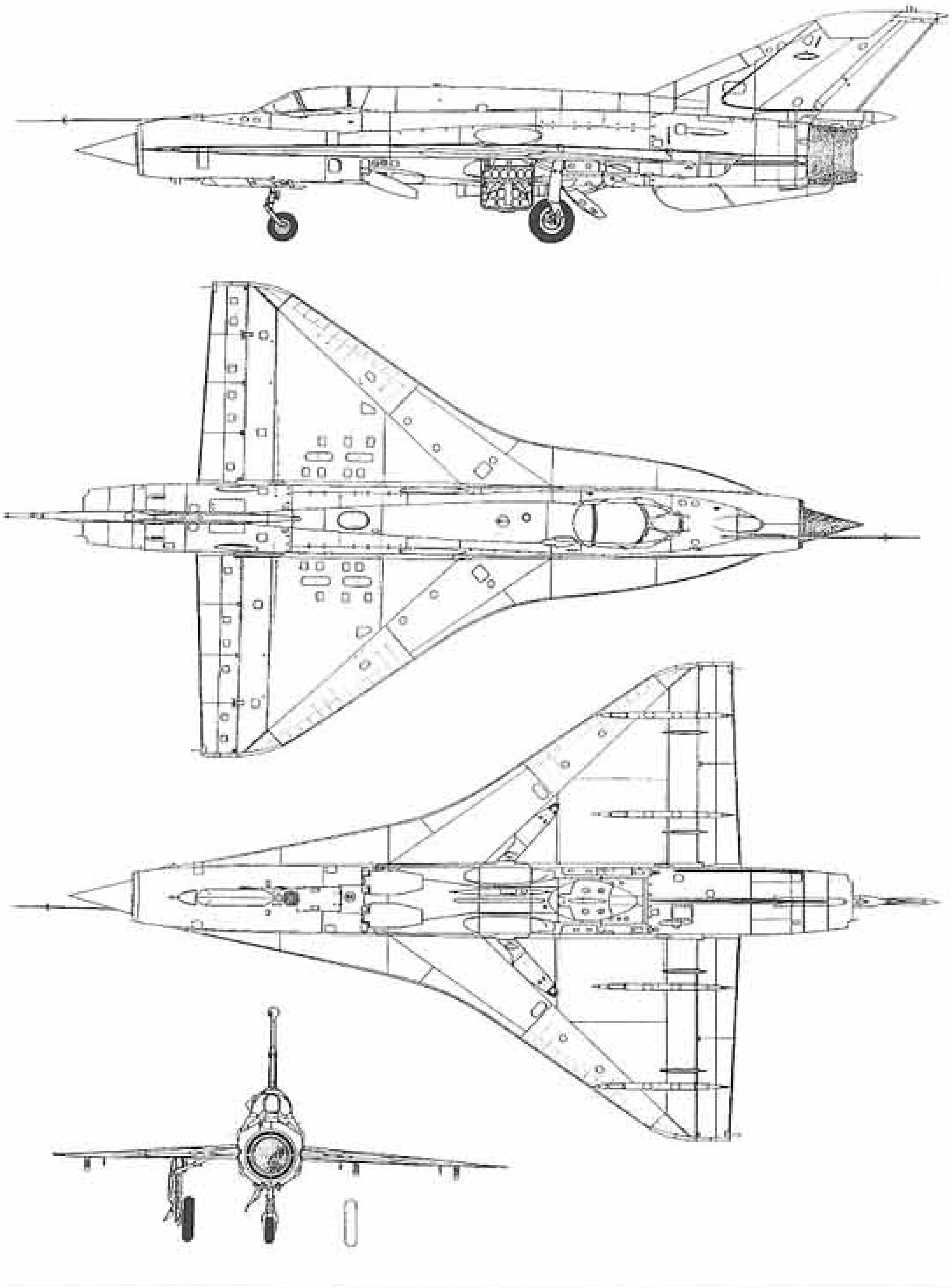
MiG-21I/1. (OKB)

MiG-21I, 21-11, *Analog*

In 1965 Mikoyan received a contract for two research aircraft to provide data to assist the design of the Tupolev Tu-144 supersonic transport. Known as the 21-11 to its designers, the MiG-21I got its popular designation from *Imitator*. Both began life on the MiG-21S assembly line, but the wing had to be almost entirely new.

It was found possible to retain the original main spar, forward beam (transverse spar) and main landing-gear bay. Around this was built a graceful wing of the ogival delta shape, with root chord extending almost from nose to tail. The 21-11 was the OKB's first (and last) jet without a horizontal tail, and it required extensive assistance from CAHI and close collaboration with the Tupolev designers, led by the founder's son, A A Tupolev. The problem was that the Mikoyan team were in totally new territory, and wanted to know how best to design the wing, while the Tupolev team wanted the 21-11 to show them how to design the much bigger wing of the SST – a 'chicken and egg' situation.

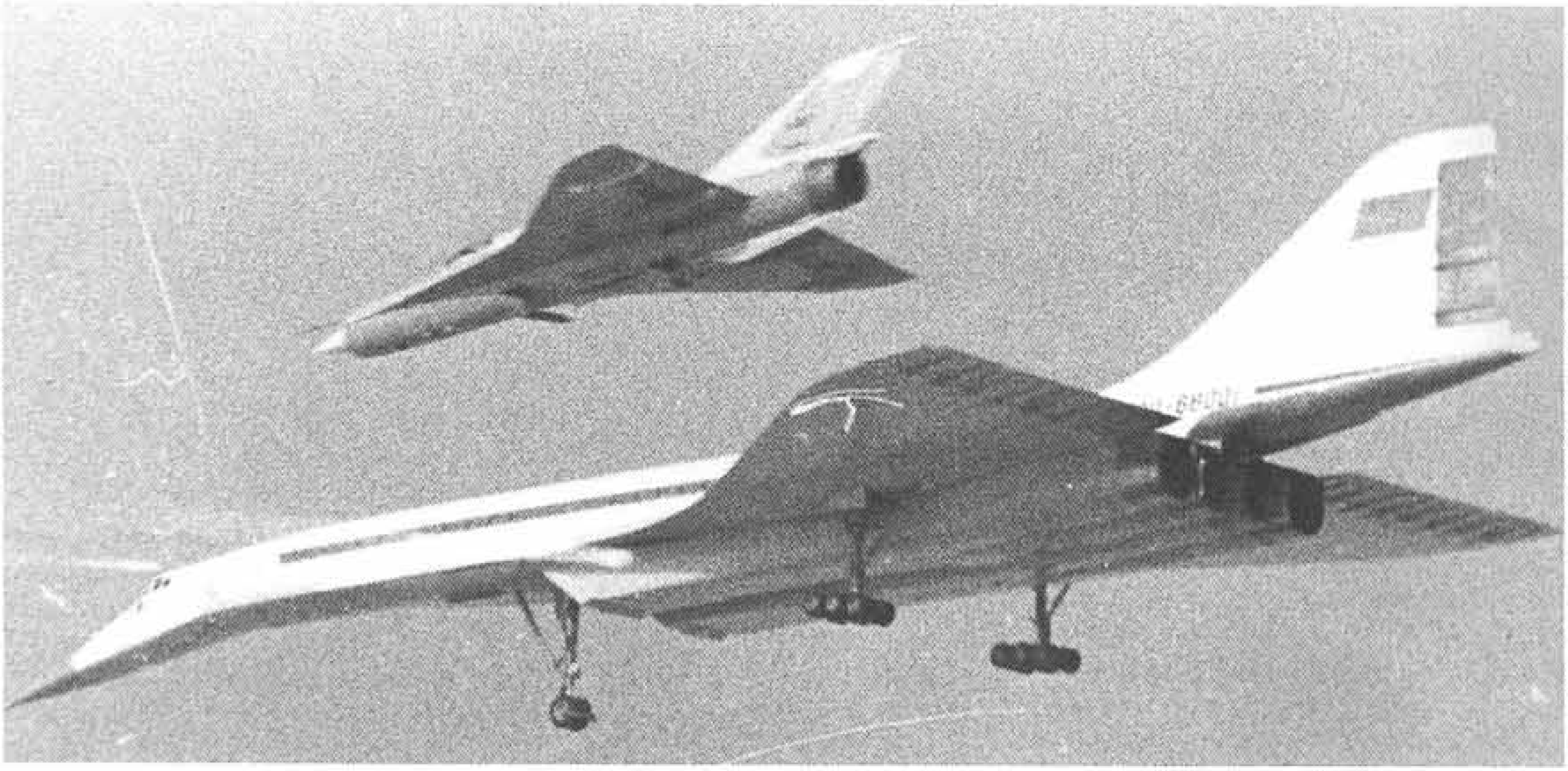
In the event it was decided to make the wing ahead of the main spar detachable, so that different shapes could be tested. The original wing had an inboard leading edge swept back at 78° (thus, angled at only 12° to the fuselage), curving gently round to an outer section swept at 55°, finally curving back to a broad squared-off tip. Behind the transverse spar the



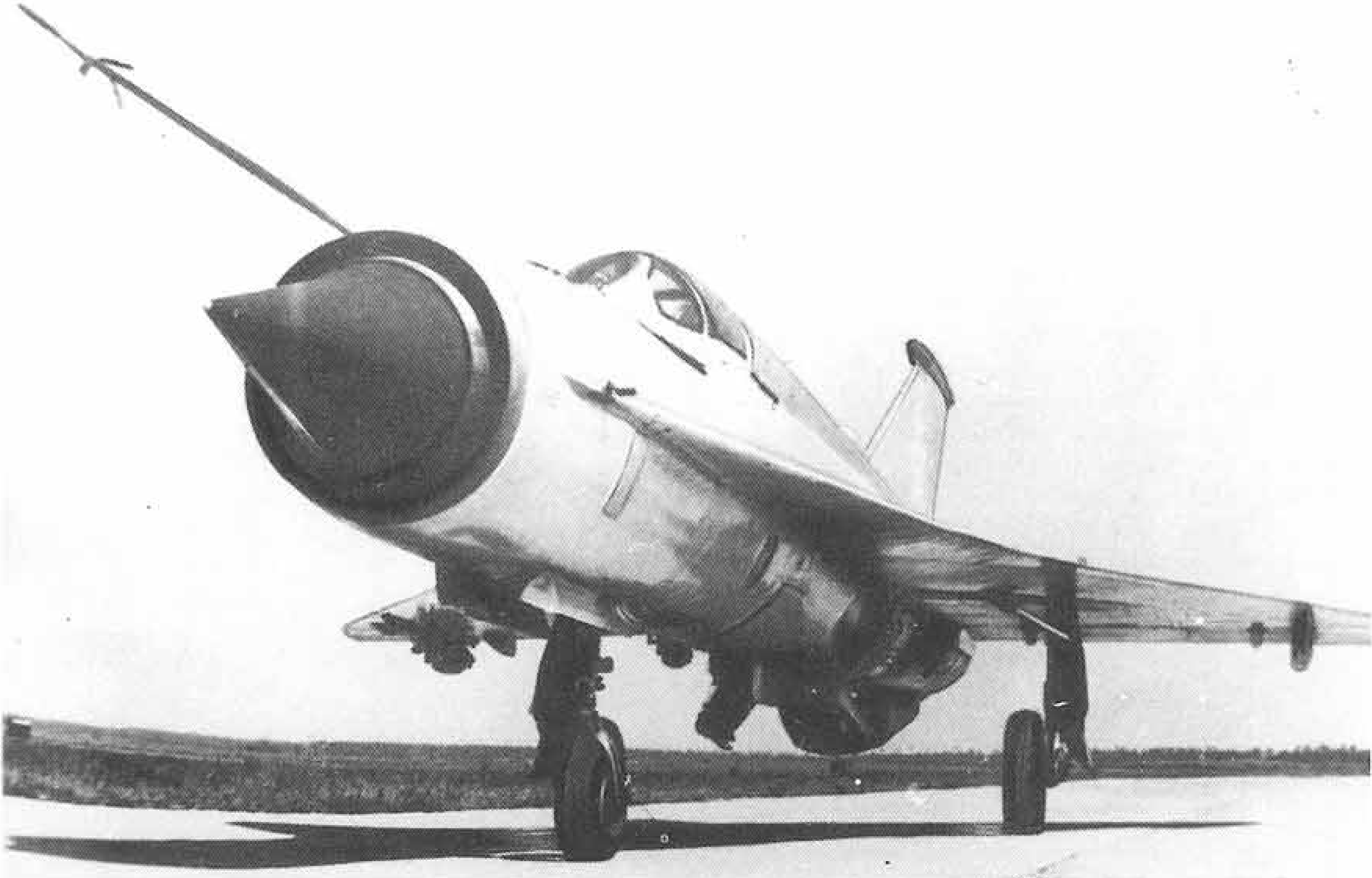
MiG-21I Analog *(side and underside, MiG-21I/1; top and front views, MiG-21I/2).*

chord was considerably increased, to carry four fully powered hinged surfaces on each wing, the inner pair serving as plain unblown flaps and the outer pair as elevons. At the junction in the centre of each pair was the power unit, the fairing for the elevon actuator extending over the full chord of the wing. Thickness/chord ratio was only 2.3 per cent inboard (one of the lowest values for any aircraft), changing to 2.5 at the tip. The leading edge had no movable surfaces, and there was no inbuilt droop (downward curvature). Adhesive tape sealed the wing/fuselage joint.

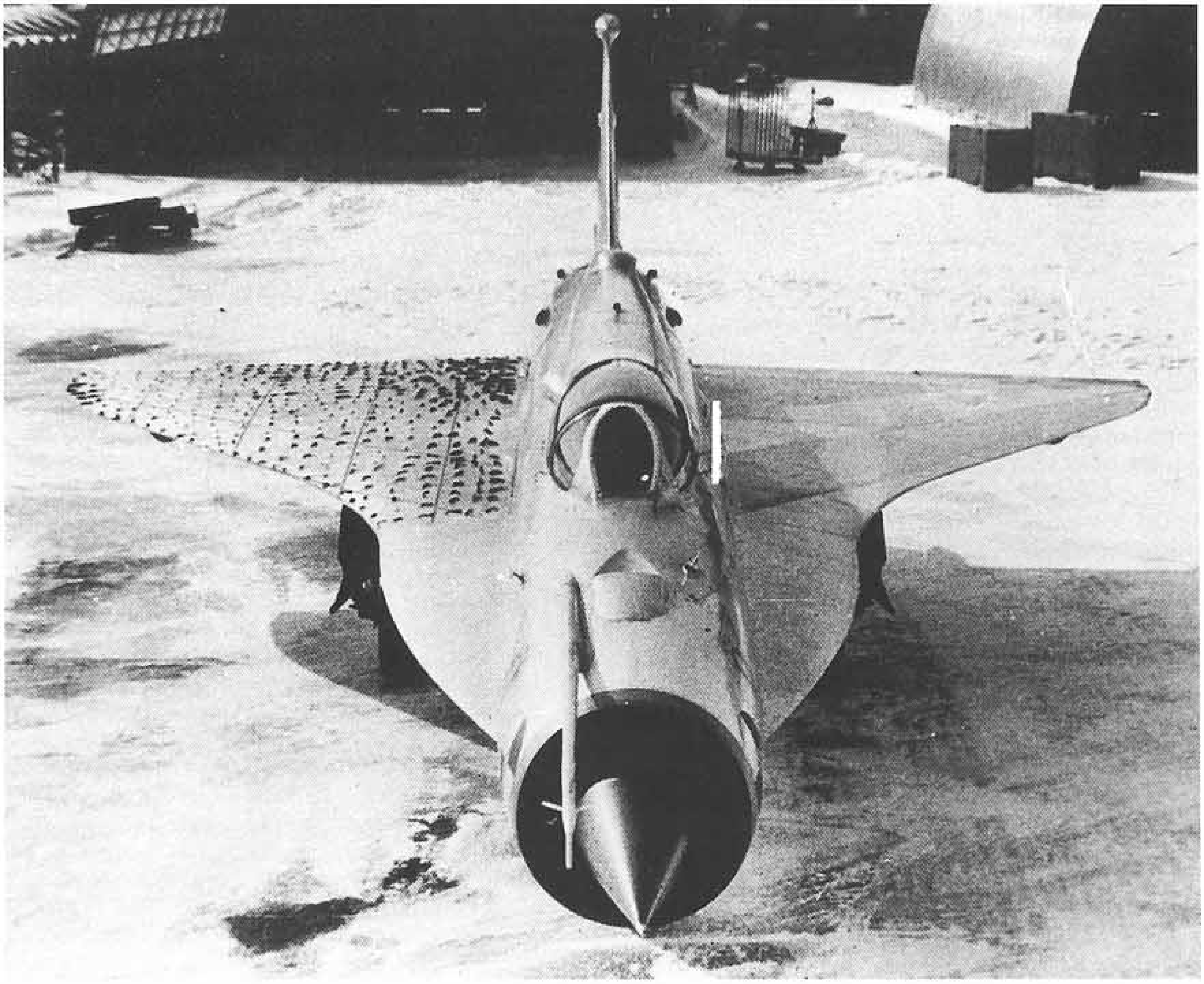
Unlike the MiG-21S the engine was an R-13-300, with the usual ratings of 4,070/6,490kg. The engine installation, airbrakes, PVD boom, SRO-2 IFF and most systems were unchanged. Fuel capacity was increased to 3,270 litres (719gal), and a rail-type telemetry antenna was added under the forward fuselage. Over a year later than Tupolev would have liked, the 21-11/1 made its first flight on 18 April 1968. The pilot



44-00 (prototype Tupolev Tu-144) on first flight with MiG-21I/1 flying chase. (Yefim Gordon archive)



MiG-21I/2 with the original wing at LII. (Yefim Gordon archive)



MiG-21I/2 with LERX and tufted wing. (Yefim Gordon archive)

was MAI test pilot Oleg V Gudkov. The aircraft was fully painted, with civil registration SSSR-1966, the original target first-flight date.

It was flown extensively, one early series of tests being with longitudinal stability varied by gradually reducing the 290kg nose ballast (simulating the radar) to zero and then progressively adding ballast in the tail. The two Tu-144 test pilots, Eduard Yelyan and Mikhail Kozlov, each flew this aircraft four times, before finally flying the Article 44-00 (Tu-144 first prototype) on 31 December 1968, with the 21-11/1 flying as chase aircraft.

The 21-11/2 differed in that the four hinged surfaces on each wing were all elevons. It made its first flight in late 1969 in the hands of LII pilot I Volk. With this aircraft different LERX (leading-edge root extensions) were investigated. Most of its flying was done with a LERX of double-ogive form which significantly increased wing area and, especially, moved the centre of lift forwards at high angles of attack. Tufts on the upper surface were photographed by a camera at the front of a pod above the fin, and later by a second camera added behind the canopy on the starboard side, looking back across the wing. At one time black/white kinetheodolite targets were painted on the right side of the nose and rear fuselage.

This aircraft did useful research for several years, finally being retired to the VVS museum. In contrast, on 28 July 1970 the 21-11/1 was flown for the first time by LII test pilot Viktor Konstantinov; apparently elated, he lost control doing unauthorized aerobatics at low level and crashed.

Together the two aircraft made 140 flights. Gudkov and Volk suggested to Mikoyan that he should build a fighter version. The only negative features were that accelerating to supersonic speed took longer than for a MiG-21S, and decelerating with airbrake was tricky, especially with centre of gravity fully aft. On the plus side were outstanding agility, especially at high altitude, and exceptional rate of roll, especially with 21-11/2. Mikoyan authorized a study of derived versions, including the 27-11 ground-attack aircraft regarded as a tailless ancestor of the MiG-27. No ASCC name was allotted. Except where noted, the data apply to both aircraft.

Span 8.15m (26ft 8¾in); length (excluding PVD boom) 14.7m (48ft 2¾in); wing area 41.1sq m (442sq ft), (21-11/2 with new LERX) 43sq m (463sq ft).

Weight empty, 5,740kg (12,654lb); internal fuel 2,715kg (5,985lb); weight loaded 8,750kg (19,290lb).

Maximum speed 1,200km/h (746mph) at sea level, 2,500km/h (1,553mph, Mach 2.35) at 13,000m (42,651ft); service ceiling over 20,000m (65,617ft); range about 1,800km (1,120 miles); takeoff run 580m (1,903ft); landing speed 225km/h (140mph); landing run 800m (2,625ft).

Chinese versions

In 1961 the governments of the USSR and China signed a licence for Chinese manufacture of the MiG-21F-13 and its R-11F-300 engine. The aircraft, designated J-7, was assigned to the Shenyang factory (already building versions of the MiG-19) and the engine, called WP-7, to the nearby engine plant, which today is LM, the Liming Engine Manufacturing Corporation. Seriously delayed by the Cultural Revolution, the first J-7 I at last flew on 17 January 1966.

At first almost all the development effort was applied to a derived twin-jet, the J-8. This was flown on 5 July 1969, but further design work was prohibited. The end of the Cultural Revolution in 1976 enabled the design teams to re-form, and subsequently various J-8 versions have flown, with ASCC name 'Finback'.

First flown on 30 December 1978, the J-7 II introduced a copy of the SK seat, with a fixed windscreen and aft-hinged canopy, longer-life WP-7B engine, parabrake under the rudder and other changes. Most J-7 II and export F-7 fighters have two 30mm guns, and the F-7BS has five pylons. The derived F-7M Airguard has a GEC-Marconi head-up display and many other upgrades. One of many export customers, Pakistan, uses the F-7P with a Martin-Baker Mk 10 zero/zero seat. The F-7MP has many further upgrades, including a FIAR Grifo radar.

First flown on 26 April 1984, the J-7 III is virtually a clone of the MiG-21MF, with the same spine, fin and 23mm gun and a WP13 copy of the R-13-300 engine.

The J-7E is characterized by a new wing: outboard of Rib 6 at the flap/aileron junction the wing is tapered on the leading and trailing edges, the leading-edge angle being only 42°. This increases span and area. The export F-7MG and PG have further upgrades, including leading- and trailing-edge manoeuvre flaps.

The JJ-7 and export FT-7 trainers have been developed by Guizhou Aviation Industrial Corporation, though their brochures do not mention that they are basically the MiG-21US. The prototype flew on 5 July 1985 and the first production FT-7 in December 1987.

The collaborative FC-1 is outside the scope of this book.

Except for the J-8, the ASCC do not appear to have allocated reporting names for any of these Chinese aircraft, most of which are at a distance indistinguishable from their MiG ancestors. As this is a book about MiG aircraft, data for the Chinese offspring are omitted.

MiG-23 and MiG-27

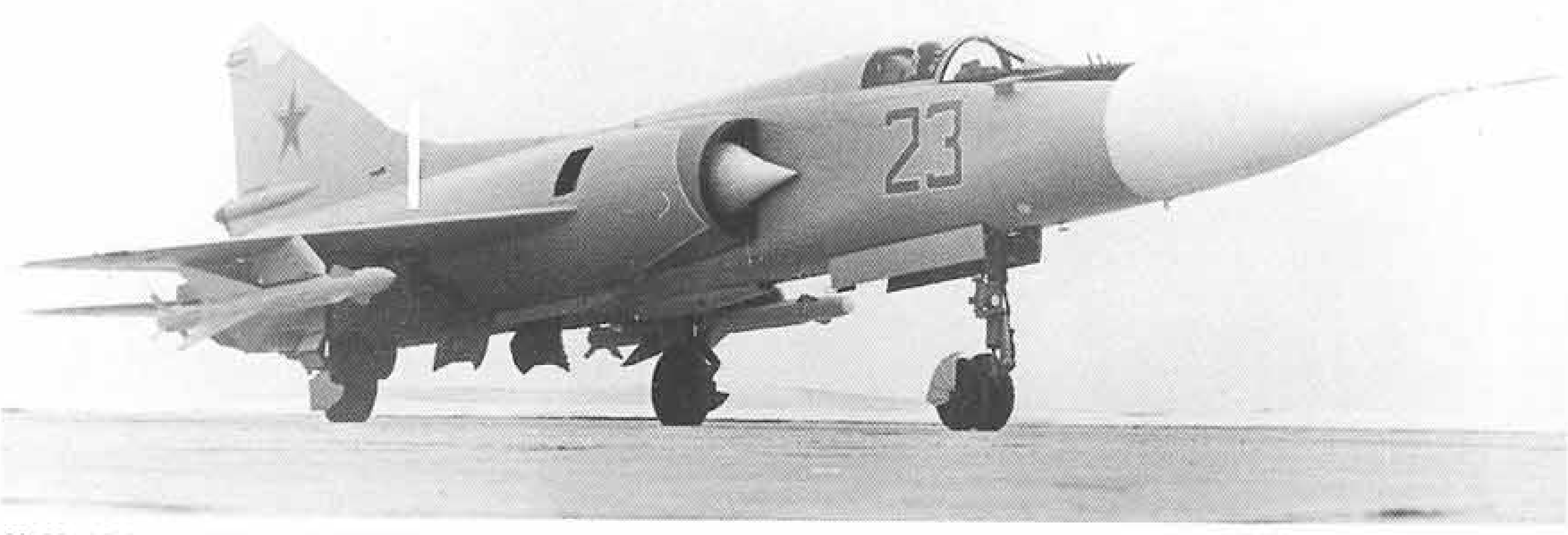
The success achieved by the OKB after the Great Patriotic War with swept-wing fighters was surpassed by the results achieved with Mach 2 tailed deltas. The only problem appeared to be that these highly supersonic aircraft had relatively small, heavily loaded wings, and despite high acceleration at takeoff the run needed was about a kilometre. By 1960 it could be seen that in an age of precision missiles airfields could be obliterated.

Today air forces seem to ignore the vulnerability of airfields, but in 1960 the only answer appeared to be a dramatic reduction in field length, so that aircraft could be dispersed and hidden. With this objective in view the OKB tested three experimental prototypes with STOL capability. One, the 23-31, has been described in the MiG-21 section. The other two aircraft were larger: the 23-01 resembled a scaled-up 23-31, and the 23-11 was a totally different design with a variable-sweep wing. Both were designed around a new engine from the Tumanskiy KB, the R-27-300 created by a team led by K Khachaturov.

23-01

This prototype was built to evaluate the performance and handling of a STOL fighter of MiG-21 layout but scaled up to match the R-27-300 main engine, with dry and afterburning thrusts of 5,200 and 7,800kg (11,464lb and 17,196lb), respectively. For takeoff and landing additional lift was provided by two RD-36-35 turbojets installed in a bay almost identical to that of the 23-31. Project manager was V A Mikoyan, second son of the general constructor's brother Anastas (President of the Supreme Soviet), and chief of technical design was A Andreyev.

Surprisingly, though geometrically identical, the wing was slightly larger than that of a blown-flap MiG-21, yet slightly smaller than the wings of the Ye-150 family. Structurally there were considerable differences, partly caused



23-01 with dummy R-23 missiles. (OKB)

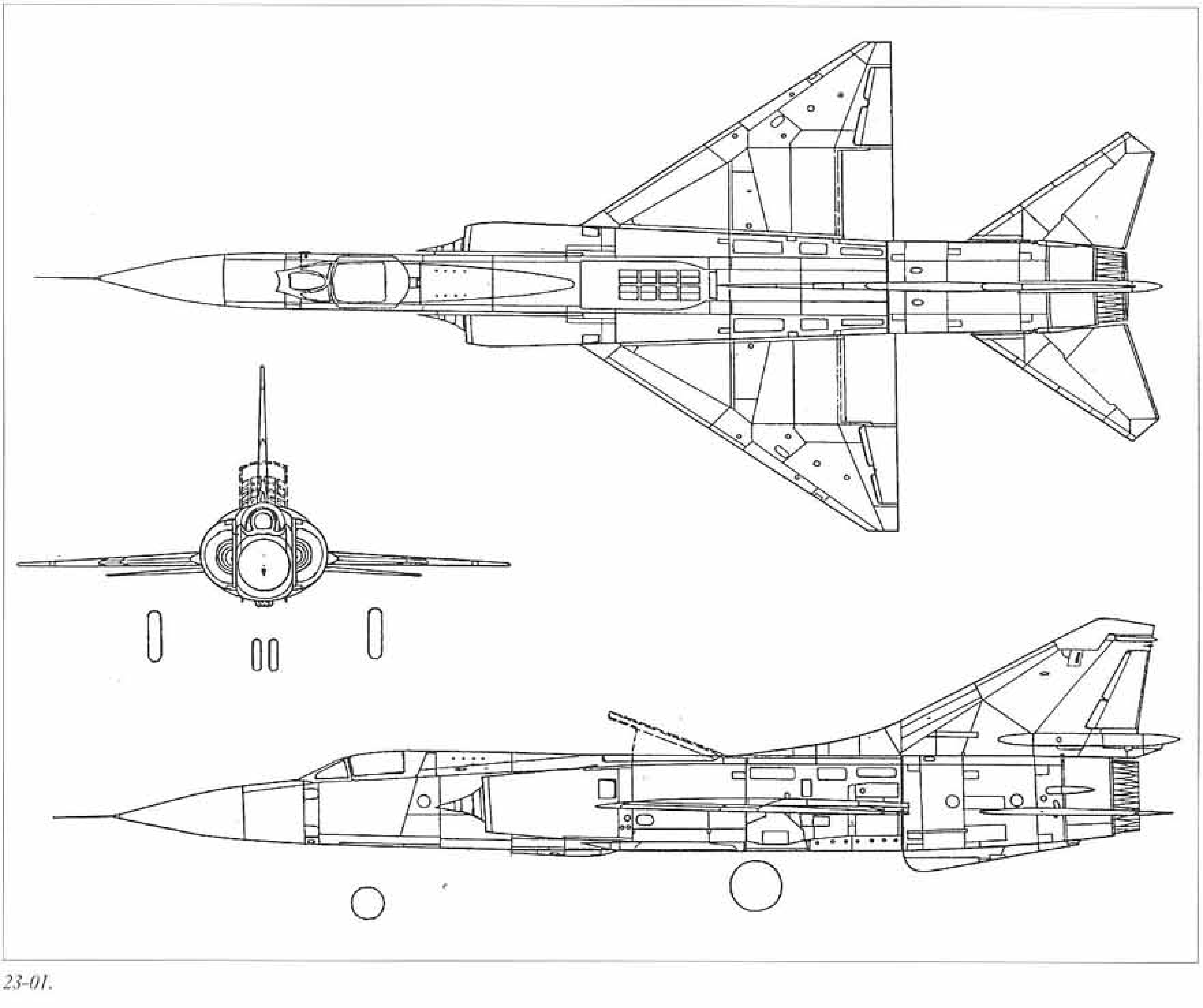
by the need for different main landing-gear geometry. The tail was also unlike any previous prototype, the one-piece 'slab' tailplanes being of completely new design. Previous MiG tailplanes had been swept and almost untapered, but the 23-01 tailplane was almost of delta shape, but with the tips cropped at the Mach angle. Their span was 4.91m (16ft 1¼in), and they were mounted on sweptback spigots more than half-way down the rear fuselage.

The fuselage was a completely new design, with the nose free to house a large radar (ballast was carried instead), so that the main engine was fed with air from semicircular inlets on each side behind the cockpit. Each inlet stood well away from the wall of the fuselage to separate boundary-layer air, and had a sharp lip and a central half-cone of four-angle Oswatitsch form translated axially by a hydraulic actuator. The inlet ducts passed on each side of the lift-engine bay and then curved sharply in to join immediately upstream of the main engine. To supply additional air at high power at low airspeeds a large square suck-in auxiliary door was provided in each duct immediately above the wing leading edge. Air bleed from the last compressor stage of the main engine supplied the blown flaps and the impingement jets for starting the lift engines.

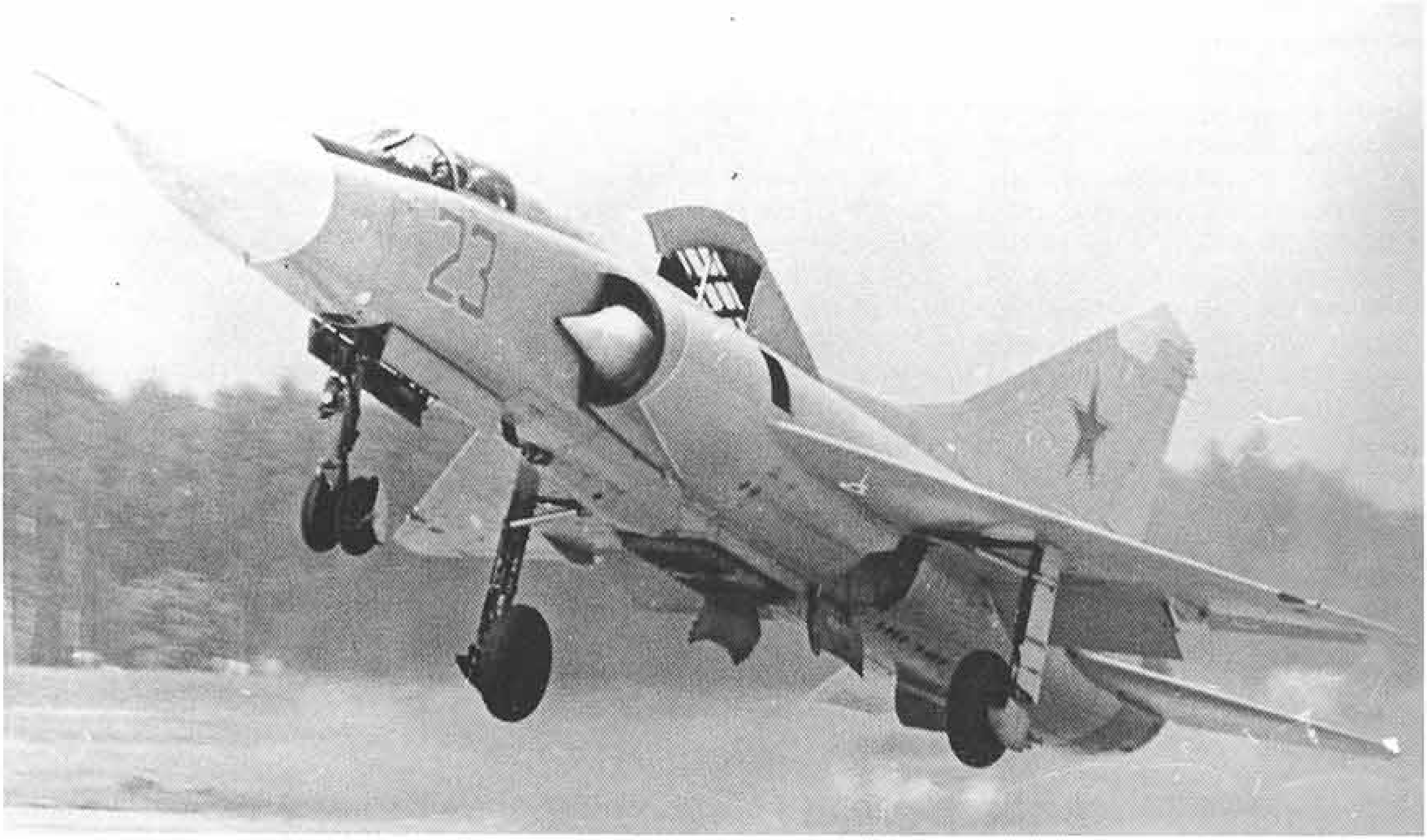
The lift-engine bay was similar to that of the 23-31, but by no means identical, with a top door of different shape, with four double pairs of inlet doors and a vertical wall on each side, but opened by an identical long-stroke actuator. The lower nozzle box was to the same design as that of the 23-31, with a cascade of seven powered deflector vanes under each jet to give ±25° vectoring. Though rated as in the 23-31 at 2,350kg (5,180lb) thrust each, the lift engines, installed at an angle of 85°, had a gross thrust of only 29.5 per cent of loaded weight. Accordingly, the 23-01 was never flown at less than 150km/h (93mph), and it was not provided with a reaction-jet flight-control system.

The landing gear was unlike that of any previous MiG aircraft. The long-stroke vertical main legs were fitted with KT-133 mainwheels with 830 × 225mm tyres and disc brakes. The units retracted inwards, the legs faired by long rectangular doors and the wheels housed almost upright in a bay closed by a door pulled up from below. The long vertical nose leg had two wheels with 520 × 125mm tyres, with MRK-30 power steering through ±90°. The steerable portion had a taxi headlight, and the wheels had a close-fitting mudguard. The unit retracted hydraulically to the rear into a long bay with twin doors. Wheelbase was 6.13m (20ft 1⅜in) and track 3.46m (11ft 4¼in).

The KM seat was installed in a cockpit with a canopy similar to that of contemporary MiG-21s and the 21-11. The 23-01 was fitted with an



23-01.



23-01. (Yefim Gordon archive)

SAU-23A automatic flight-control system, but during a few of its brief test flights this was inoperative. The braking parachute, installed in a tube under the rudder, was of the PT-10370-65 type, with a cruciform canopy of 21sq m (226sq ft) area. Where an airbrake might have been fitted there was a GSh-23L gun (not operative), and when first completed two mock-up missiles (Vympel R-23R and R-23T) were carried on underwing pylons. Actual missiles could not have been fired because there was no radar fire-control. The few avionics included RSIU-5V radio, SRO-2 IFF, an RV-2M radar altimeter, a simple nose air-data boom without AOA/yaw vanes, an auxiliary pitot near the windscreen and a yaw weathercock under the fuselage. Apart from having a white simulated radome the 23-01 was painted grey, with red trim and call-sign 'Red 23'.

It was first flown by Ostapenko on 3 April 1967. He was soon joined by Fedotov, and factory test manager was V M Timofeyev. Long before it was completed, Mikoyan had decided this was not the way to go, but – possibly with one eye on disinformation – the 23-01 was kept serviceable until the public airshow on 9 July 1967, when Ostapenko put on a brief demonstration. This resulted in the ASCC calling it 'Faithless'.

Span 7.72m (25ft 3⅞in); length (excluding PVD) 16.8m (55ft 1⅜in); wing area 40sq m (430.6sq ft).

Empty weight 12,020kg (26,500lb); internal fuel about 3,700kg (8,157lb); weight loaded 16,000kg (35,273lb).

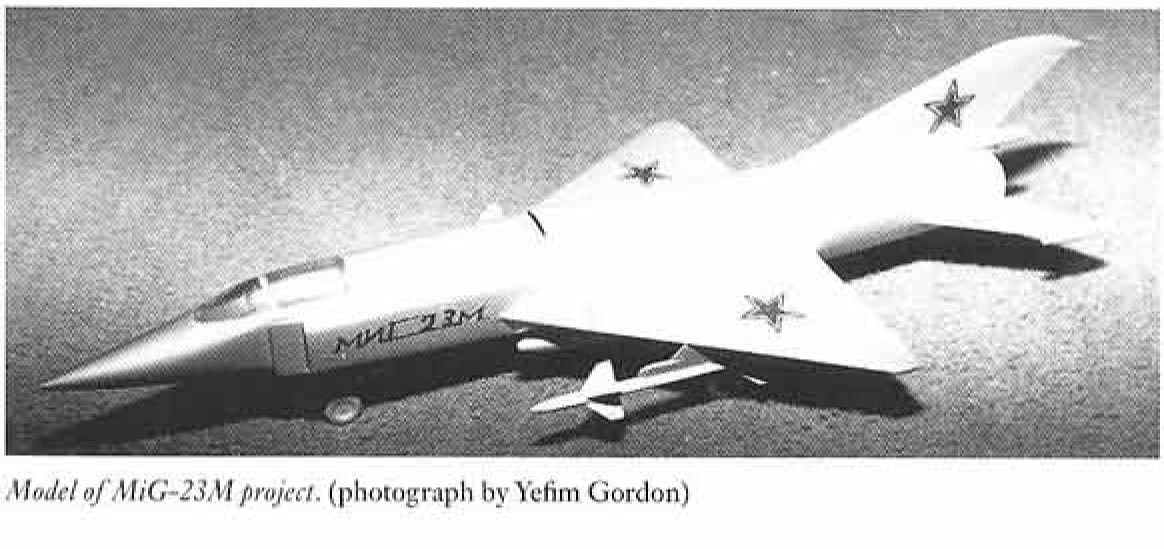
Performance not recorded, except takeoff run (light weight) 180–200m (591–656ft) and landing run (with parabrake) 250m (820ft).

MiG-23M project

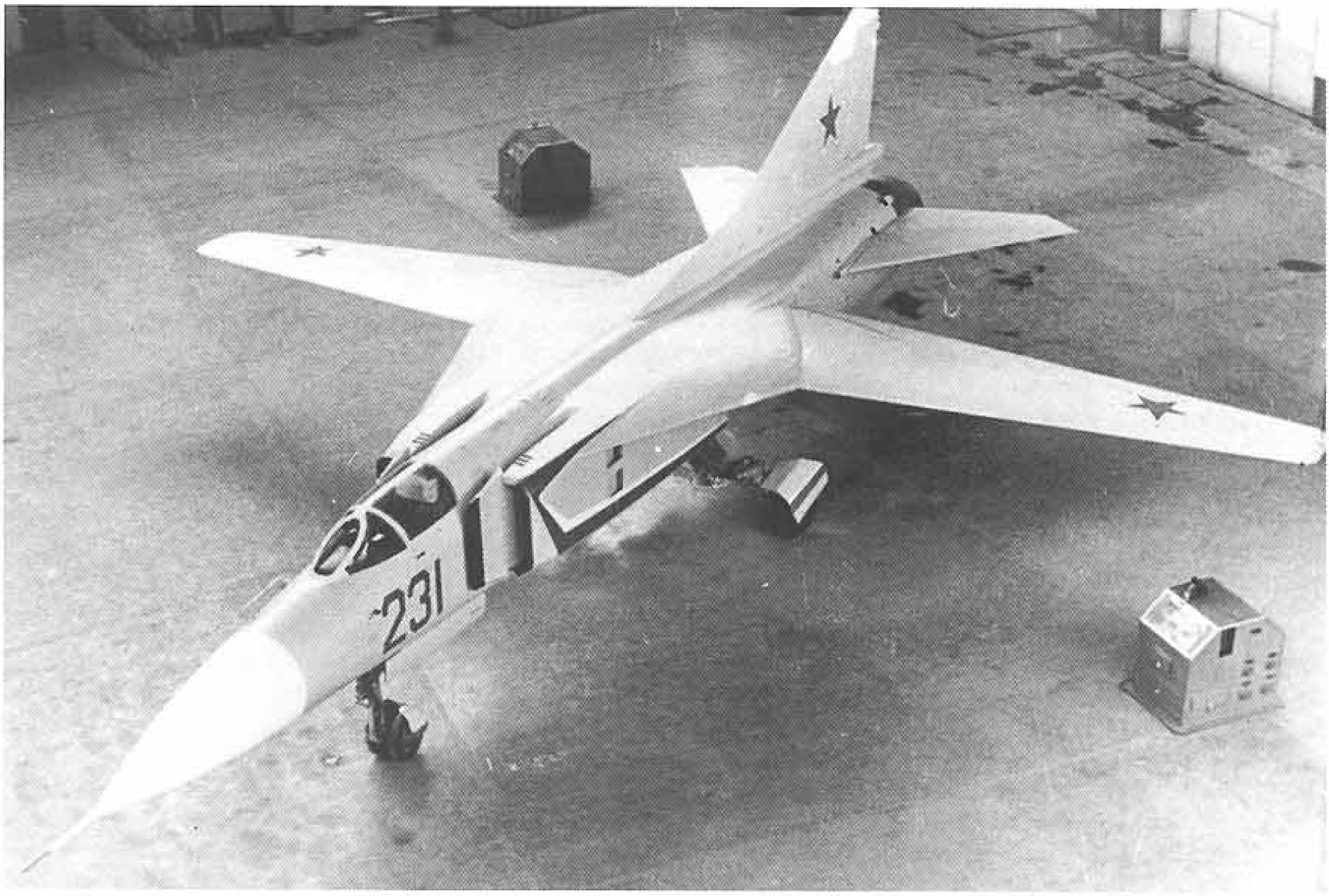
When the 23-01 was designed, the OKB had no experience with lateral inlets. This unbuilt project was essentially a 23-01 fitted with the two-dimensional variable inlets of the 23-11 and the tail of the Ye-8. The display model shows a small nose without radar and pylons under the wings and fuselage. Later the designation was used for a series aircraft.

23-11

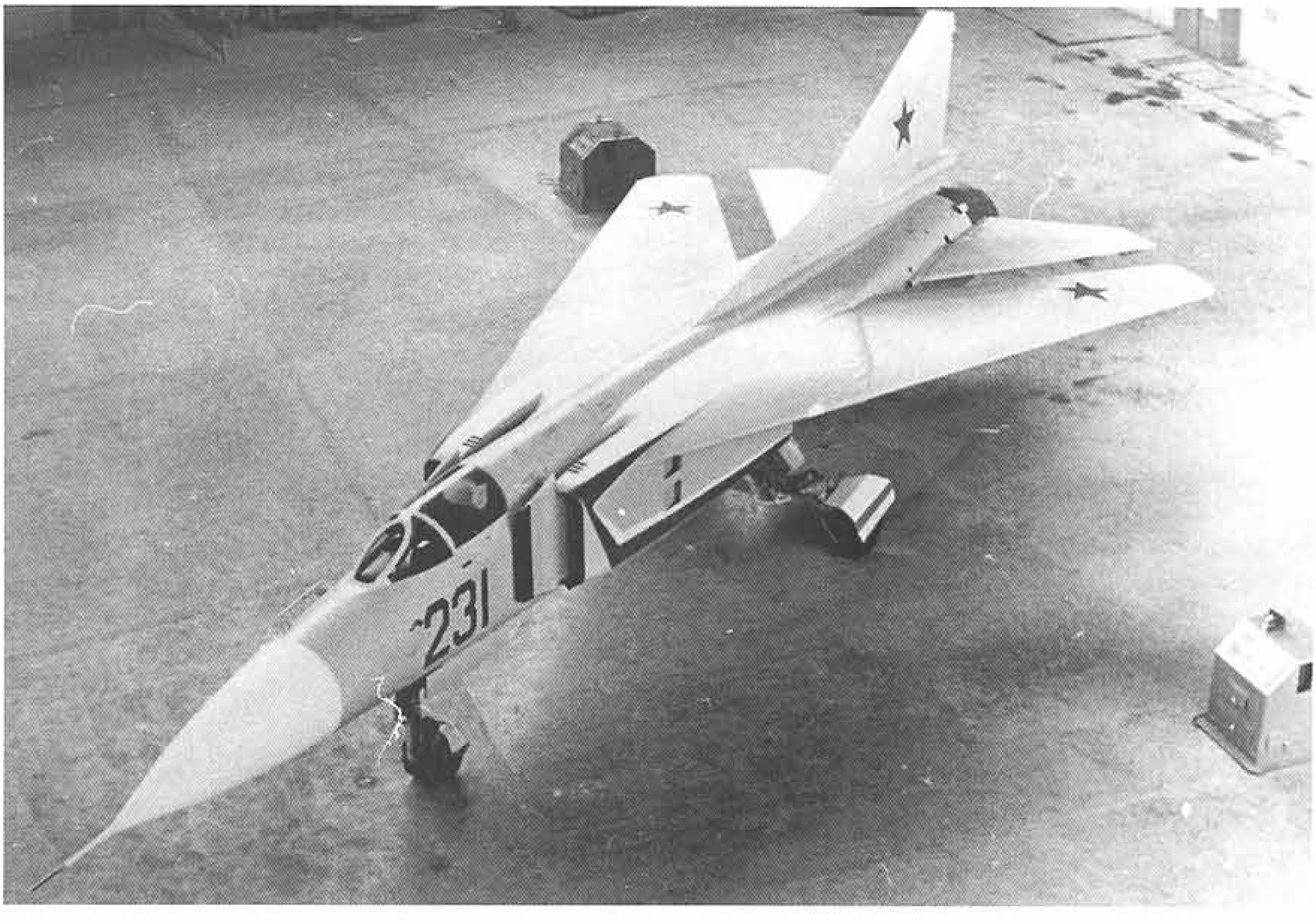
From the start of its detailed STOL studies in 1964 the MiG OKB almost universally considered that the variable-sweep 'swing wing' would be found superior to the addition of separate lifting turbojets. In that year work was concentrated on the latter scheme, with the 23-01, but in 1965 the OKB was ordered to build a second type of MiG-23 with a variable-geometry high-lift wing. Mikoyan assigned former test pilot Grigoriy Aleksandrovich Sedov as leader-engineer, with Mikhail R Waldenburg as his deputy. MKB (preliminary design bureau) *Rodina* (motherland), under general designer



Model of MiG-23M project. (photograph by Yefim Gordon)



23-11/1 with wings at 16°. (Yefim Gordon archive)



23-11/1 with wings at 72°. (Yefim Gordon archive)

Selivanov, was assigned the responsibility for the wing pivot and variable-geometry actuation system.

Mikoyan was so sure of the importance of this alternative solution to the STOL problem that he obtained contract cover for not one but ten 23-11 development aircraft. The first, 23-11/1, had callsign '231'; the second was callsign '232' and so on until the last, 23-11/10, which was callsign '230'.

By this time full details were known of the American General Dynamics F-111, and this exerted a significant influence, because variable-sweep was a new kind of wing to the OKB. The pivoted outer wings were thus very similar to those of the US aircraft, with the same nominal sweep angles of 16° for takeoff and landing, 45° as an intermediate position and 72° for supersonic flight. In exactly the same way, these wings were pivoted to a large fixed centre section mounted close to the top of the fuselage.

Putting the wing so high meant that, for the first time since the MiG-9, the wing structure could be carried across from tip to tip. The basis of the whole aircraft was a fuselage section bounded by Frame 18 at the front and Frame 20 at the back. This was constructed of welded VNS-2 high-strength steel, and incorporated Tank 2 (an integral sealed structure), which extended on each side to carry the wing pivots 1.5m (59in) from the centreline. Immediately below this was the central duct to the engine.

Ahead of this on each side of the fuselage was added secondary structure to give a leading-edge sweep angle of 72°, matching the maximum angle of the outer wings. A second addition at the rear was bounded by an open rib-like member set at 30° to the fuselage. At 16° sweep the outer wing butted against this, the gap sealed by a metal-edged Teflon strip on the fixed portion. At greater sweep the pivoting wing entered the fixed portion, which had flexible surfaces formed from springy plates which kept the edge strip pressed against the moving inboard flap, which was protected by a curved strip of steel above and below.

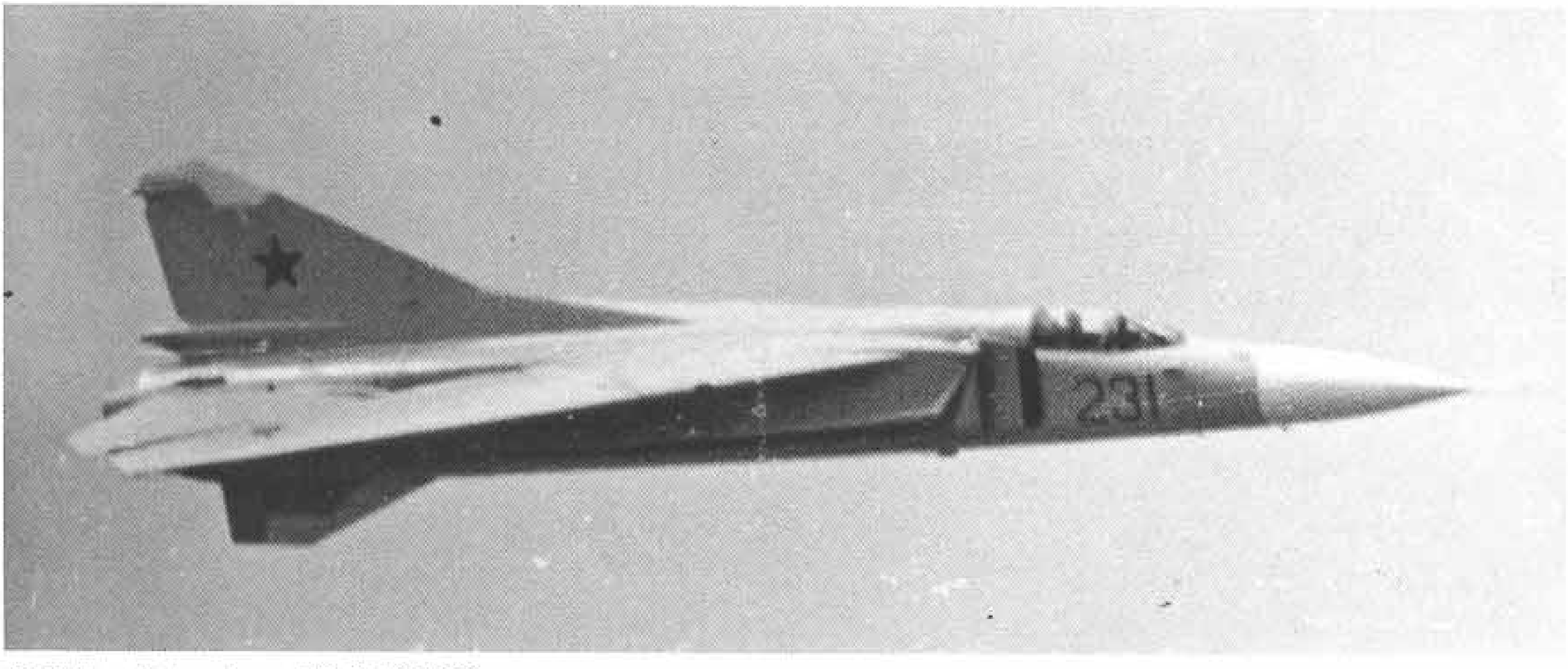
Basic aerofoil profile of the outer wing was SR-12s, with a thickness/chord ratio at zero sweep of 5.5 to 6.5 per cent. On the leading edge were three sections of pivoted droop flap, driven hydraulically and interlinked with the four sections of slotted trailing-edge flap. At takeoff the leading-edge flaps were depressed 17° and the trailing edge at 25°. For landing the leading edge was at 19° and the trailing edge at 50°.

After takeoff the pilot could select wing sweep, the limit available being governed by q (dynamic pressure) and the SOUA active AOA-limiting subsystem. The wings were driven by the SPK-1 system in which a control lever on the left coaming signalled main and standby hydraulic motors driving a ball-bearing screwjack mounted transversely to drive horns on the front of the main-spar root. Either motor could drive the wings at half speed, the linkage precluding asymmetric sweep. Structural problems, notably the nonredundant pivots, limited design load factor to only 3.1g, but production aircraft were to be designed to a factor of 7. As soon as the wing sweep was actuated, the leading and trailing flaps were brought to 0°, and the linkage between them disconnected.

On the upper surface ahead of the two middle flap sections were two spoilers, normally recessed but used in subsonic flight to augment roll control, one or other being driven hydraulically to up to 45°. On landing, compression of the main oleos immediately opened both sets of spoilers to go to 45° to kill lift. In flight, as soon as the pilot selected sweep beyond 45° spoiler authority (limiting angle) began to be reduced, until at 72° the spoilers were locked inoperative.

Thus, at supersonic speeds roll control, as well as control in pitch, was provided solely by the slab tailerons. These had a leading-edge angle of 57° and span of 5.3m (17ft 4⅝in), and were mounted at the same level as the wing very near the top of the fuselage. Each taileron was mounted on a swept spigot on Frame 31 outboard of a small fixed root, with a cooling ram inlet at its leading edge. The vertical tail was almost identical to that of the 23-01, with a leading-edge sweep of 65° and kink to a dorsal fin. The rudder was driven by an irreversible power unit, with spring feel. Structurally, the rudder, the rear part of each taileron and the wing flaps were all aluminium honeycomb.

In the course of design it appeared likely that yaw stability would in some circumstances be marginal, and merely making the fin even bigger appeared to be counterproductive in inducing undesired roll. The solution, which was


23-11/1 on display, wings at 72°. (RART/GP)

one of many novel ideas patented, was to add a fin under the rear fuselage. This had to be more powerful than the keels seen on previous MiG fighters, and its lower part was mounted on hinges. When the landing gear was selected down, a hydraulic ball-bearing screw-jack pulled the underfin up through 90° to the right to lie horizontally.

The engine was the Khachaturov R-27-300, rated at 5,200kg (11,464lb) dry and 7,800kg (17,196lb) with afterburner. This was a very conservative initial rating, and it almost eliminated the fear of engine failure which had plagued most earlier supersonic MiG aircraft. Unlike the 23-01, the inlets were vertical two-dimensional rectangles, with a large inner splitter plate 55mm (2.17in) away from the fuselage. Centred in this gap was a ram inlet for the cockpit environmental control system and avionics cooling. Above and below were channels to divert boundary-layer air.

With the help of CIAM the OKB created their first two-dimensional variable-geometry inlet. The splitter plate itself was fixed. On its rear edge was a piano hinge to two hinged walls in tandem which varied throat area and wall angle under the control of a UVD-23 hydro-electronic system activated at all Mach numbers above 1.15. It controlled shock formation, the escape of boundary-layer air through vertical rows of wall perforations, and engine pressure ratio, which reduced from 11 at Mach 1.15 to 4 at over Mach 2, whilst simultaneously adjusting the taileron neutral angle.

Each inlet duct was provided with two rectangular auxiliary suck-in relief doors under the fixed wing glove, and there were large pressure-relief holes in the underside of the engine bay between Frames 24 and 28. Near the top the same bay incorporated the boxes which accommodated the inner ends of the wing flaps at 72° sweep.

A total of 4,250 litres (935gal) of fuel was housed in nine tanks, which for the first time were all of the structurally sealed integral type. Three were in the fuselage, 1,920 litres between the inlet ducts, 820 litres in the wing centre box and 710 litres between Frame 25 and the end of the main fuselage at Frame 28. Three occupied the inter-spar space in each wing, the inner being of 200 litres, the centre 137.5 and the outer 62.5, all feeding through pivoting telescopic pipes near the wing hinge. In production aircraft there was also provision for a drop tank and for a 28lit (6.16gal) tank of injection water in the rear fuselage.

The nose landing gear was the same as that fitted to the 23-01. Each main unit had a J-shaped leg which on the ground extended almost horizontally out from the fuselage to carry a J-shaped trailing lever on which was mounted the axle for a KT-133 wheel with a disc brake and 830 × 225mm tyre. A vertical hydraulic jack pulled the legs up and inwards while the trailing arm was pulled downwards to stow the wheel diagonally in the side of the fuselage, in a bay closed by a door curved round the wheel and a second hinged to the bottom of the bay and pulled up by its own jack. Track was 2.658m (8ft 8⅝in) – it was a struggle to achieve even this – and wheelbase 5.772m (18ft 11¼in).

To change the engine, the rear fuselage disconnected at Frames 28 and 28A. Frame 31 carried not only the hinge for the ventral fin but also the main spar of the upper fin and the hinges for four long-chord rectangular door-type airbrakes arranged above and below the tailerons on each side. The braking parachute installation was as in the 23-01. The rear fuselage projected beyond the tail surfaces, and the engine nozzle, with sixteen inner and outer controllable petal flaps, projected considerably further still. After completion the 23-11 was given a cooling inlet above the rear fuselage on the left side only.

The 23-11/1 had a ballast weight in lieu of the intended radar, and the planned GSh-23L gun and weapon pylons were not installed. On the nose was a simple q-sensing PVD boom, a second pitot head was near the windscreen and a AOA/yaw sensor was mounted under the forward fuselage. The autopilot was designated SAU-23A. A retractable landing light was installed under each side of the forward fuselage, and pointed static-discharge wires projected behind each wingtip and the trailing edges of the tail surfaces.

The 23-11/1 was taken to Zhukovskiy on 26 May 1967, and first flown by Fedotov on 10 June. The full range of wing sweep was tested on Flight 2. Serviceability was excellent, and he was able to fly thirteen times before making an impressive demonstration at the Domodyedovo airshow on 9 July. No engine changes were needed, but the engine reached its 25hr life limit on Flight 45 at the end of 1967. Despite the greater engine power, fuel burn per kilometre averaged 25 per cent less than that of a MiG-21.

In early 1968 this aircraft was fitted with a second engine, an R-27F-300 of unchanged ratings. Like subsequent prototypes it also received the three-axis AP-155 autopilot, the gun and four pylons under the inlet ducts and the outer ends of the wing gloves, with APU-13 launchers for R-3 missiles and APU-23 launchers for the K-23 (prototype R-23). The first two prototypes, '231' and '232', had no radar and could not fire live R-23 missiles. The first aircraft with the powerful *Sapfir*-23 radar was the third, '233'. The next aircraft, '234', was unique in having the nose PVD boom displaced to the 10 o'clock position on the nose, to improve radar performance.

Factory testing was completed after 23-11/1 had made ninety-seven flights in July 1968. Ostapenko and Komarov made sixteen firings of inert missiles with the first two prototypes. Both these aircraft were eventually sent to the VVS museum, both painted as '231' (the true 23-11/1 has extra painted 'arrow' trim). The 23-11/4 is at the Moscow Aeronautical Institute. After its public appearance on 9 July 1967 the 23-11/1 was given the ASCC name 'Flogger'.

Span (16°) 13.965m (45ft 9¾in), (72°) 7.779m (25ft 6¼in); length (excluding PVD boom) 15.795m (51ft 9⅞in); wing area (16°) 32.1sq m (345.5sq ft), (72°) 29.89sq m (321.75sq ft).

Weight empty 9,290kg (20,481lb); internal fuel 3,530kg (7,782lb); weight loaded 12,860kg (28,351lb), (maximum, four missiles) 13,300kg (29,321lb).

Maximum indicated airspeed 1,178km/h (732mph); maximum speed (clean, 72°) 2,240km/h (1,392mph, Mach 2.10) at 13,600m (44,620ft), (two K-23) 2,255km/h at 13,400m (43,963ft), (four K-23) 2,025km/h at 12,800m (41,994ft), no climb figures; service ceiling 17,200m (56,430ft); range (16°, two missiles) 2,045km (1,271 miles); takeoff speed (16°) 270km/h (168mph); takeoff run 320m (1,050ft); landing speed 230km/h (143mph); landing run 440m (1,444ft) or 750m (2,461ft) without parabrake.

MiG-23S, 23-11S, 22

The first series aircraft, which retained the OKB's basic *Izdeliye* number of 23-11, received Service designation MiG-23S from the *Sapfir* radar. To confuse the issue further, the VVS allotted the

Izdeliye number of 22, while the engine, the R-27F2-300, had its own *Izdeliye* number 47. This engine was installationally identical to the R-27F-300, but had dry and afterburning ratings of 6,900kg and 10,000kg (15,212lb and 22,046lb), respectively.

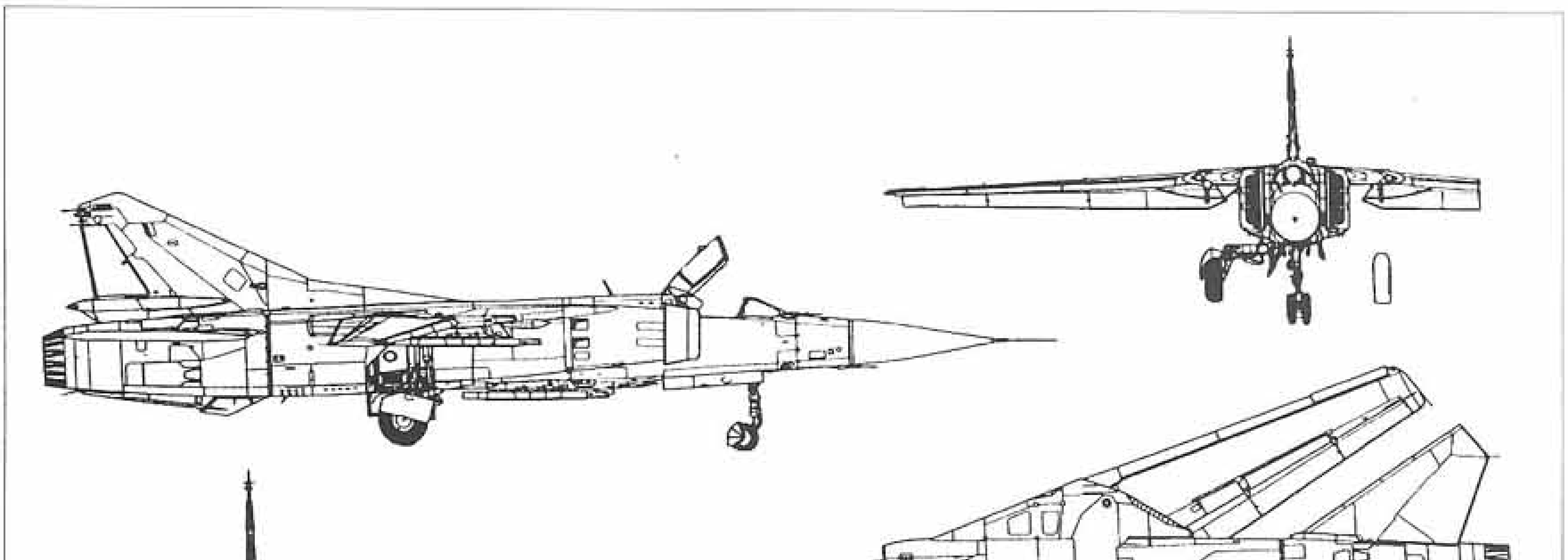
The MiG-23S was never regarded as more than an interim aircraft. The design load factor was raised only to 5. The underfin was moved one frame to the rear. Downstream of the leading-edge kink at Frame 26 the fin was moved back two frames, 0.6m (24in), which enlarged the dorsal fin. The horizontal tail surfaces were also moved back two frames and given 40mm (1.6in) wide 'knife' strips over the inboard 0.4m (15¾in) of the trailing edge. The airbrakes were enlarged and strengthened for unlimited IAS by two external ribs.

By this time the aerodynamicists had come up with a better wing with which combat manoeuvrability was much enhanced, but this was not fitted. In addition, though the large nose radome was considered quite an achievement, and made of a new dielectric glassfibre, the production radar was not ready, and the first series had to have the S-21 or *Sapfir*-21, the same as later MiG-21s, so all these aircraft were relegated to a training role.

New equipment included provision for a centreline pylon carrying a drop tank of 490 or 800 litres (107 or 176gal) capacity, a drop-down windmill-driven emergency hydraulic pump to maintain flight control after engine failure, a retractable landing light under each inlet duct (instead of under the nose), mainwheel tyres increased in width to 830 × 300mm, all wheels fitted with antiskid multidisc brakes, and an electrically heated rear-view mirror in the top of the canopy. The SAU-23 flight-control system could be used in automatic interceptions and also for coupled ILS landings. Other avionics included the ARK-10 radio compass, SARP-12G centralized fault-warning system and the ASP-PF sight with a combined display for the radar and for the TP-23 IR detector, which became available during MiG-23S production and was retrofitted in a chisel-nose gondola ahead of the nose landing-gear unit.

The installation of the GSh-23L gun was similar to that in later MiG-21s, though the 200/250-round magazine was a demountable box. The two fuselage and two glove pylons were the same as in full production aircraft, but the S-21 radar meant that the much more powerful radar-guided R-23R missile could not be used. Accordingly only fifty MiG-23S aircraft were built, by MMZ *Znamya Truda* in 1969.

The first MiG-23S began flight testing on 23 May 1969. The whole



MiG-23S.

batch were assigned to Belarus, the first aircraft going in summer 1970 to the Lipetsk combat training centre. Some later received *Sapfir* S-23 radar. The ASCC name was 'Flogger-A'.

Dimensions unchanged.

Weight empty 10,460kg (23,060lb); internal fuel 3,530kg (7,782lb); weight loaded (normal, i.e. clean) 14,600kg (32,187lb), (maximum) not recorded.

Performance almost unchanged; limiting Mach number 2.27 clean, 1.8 with missiles; service ceiling (clean) 18,000m (59,055ft), (four missiles) 16,500m (54,134ft); range (clean) 1,800km (1,118 miles), (800lit tank) 2,500km (1,553 miles); takeoff run 650m (2,133ft); landing speed 240km/h (149mph); landing run 550m (1,804ft).

MiG-23 *etalon* 1971, 2

Meaning '1971 standard', this was the second production version. The VVS *Izdeliye* number was 2. Externally this differed in having the second design of outer wing. This was redesigned ahead of the front spar. Chord of the new section increased progressively from the tip to near the root, where it ended in a prominent dogtooth discontinuity. The leading-edge flaps were locked in the first batch and omitted in later aircraft. This modification increased leading-edge sweep to a minimum of 18°40′ and a maximum of 74°40′, area being significantly increased. In theory the new wing was able to use the design load factor of 7, but the carry-through box and pivots limited g to 3.5.

The engine was the R-27F2M-300, with unchanged ratings. All these aircraft had the operative S-23 radar. They also made use of the rear-fuselage Tank 4, which in earlier versions had not been sealed. Only a small production series were made by the *Znamya Truda* factory, in 1971, equipping 'three or four regiments'. No separate ASCC name is known. Data are essentially the same as for the MiG-23S, apart from greater wing area (*see* MiG-23M), and slightly increased clean loaded weight and range.

MiG-23M, 23-11M, 2M

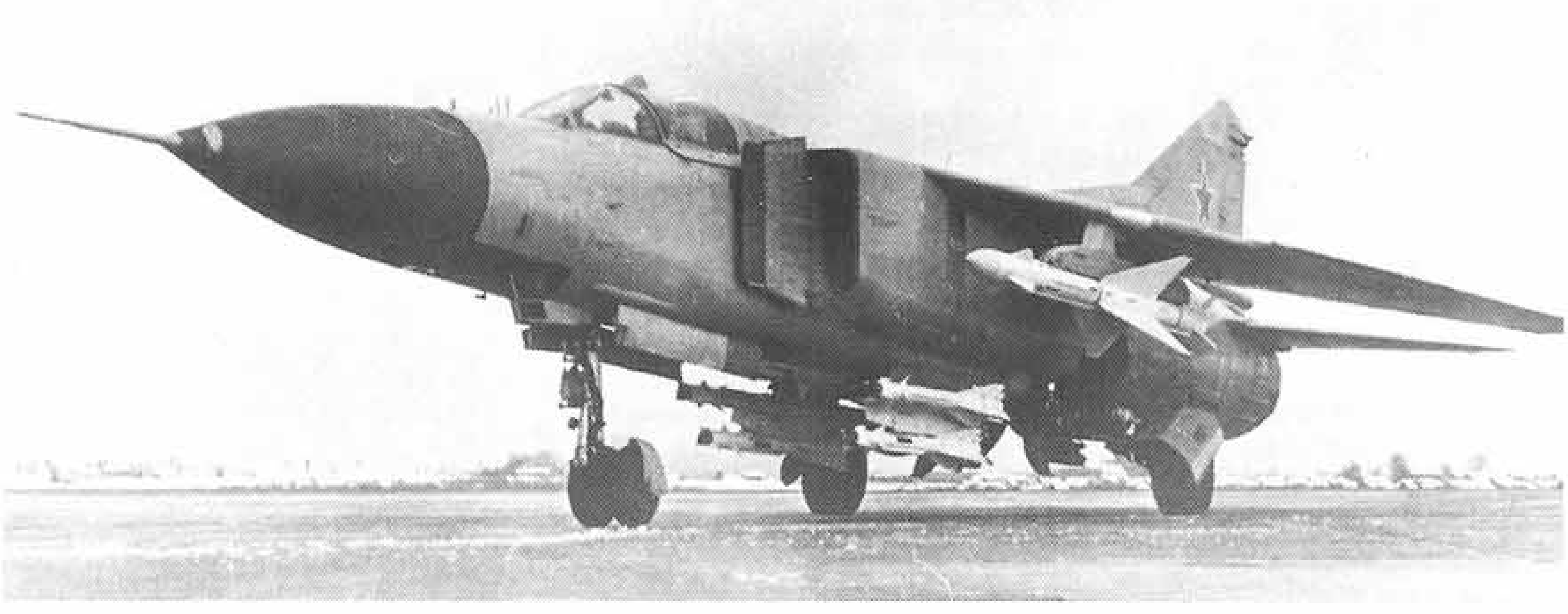
Identified by the VVS *Izdeliye* number 2M, this was the first major production version, dating from 1972 and produced in large numbers to 1977. It was the first of the new variable-sweep family to be without serious deficiencies, and cleared for front-line service. It was distinguished by a new engine and a third design of wing, but from the operational viewpoint the most important advance is that it at last had the new radar, enabling it to illuminate targets for the K-23 (produced in series as the R-23) missile.

The new engine was Khachaturov's R-29-300 (*see* Appendix 1). It was longer and heavier than the R-27, and its afterburner was not only enlarged in diameter but fully variable with stepless control. Dry and afterburning ratings were considerably increased to 8,300kg (18,298lb) and 12,200kg (26,896lb), respectively. At that time this was the world's most powerful fighter engine. About eighteen months after entering service the afterburning thrust was requalified at 12,500kg (27,557lb).

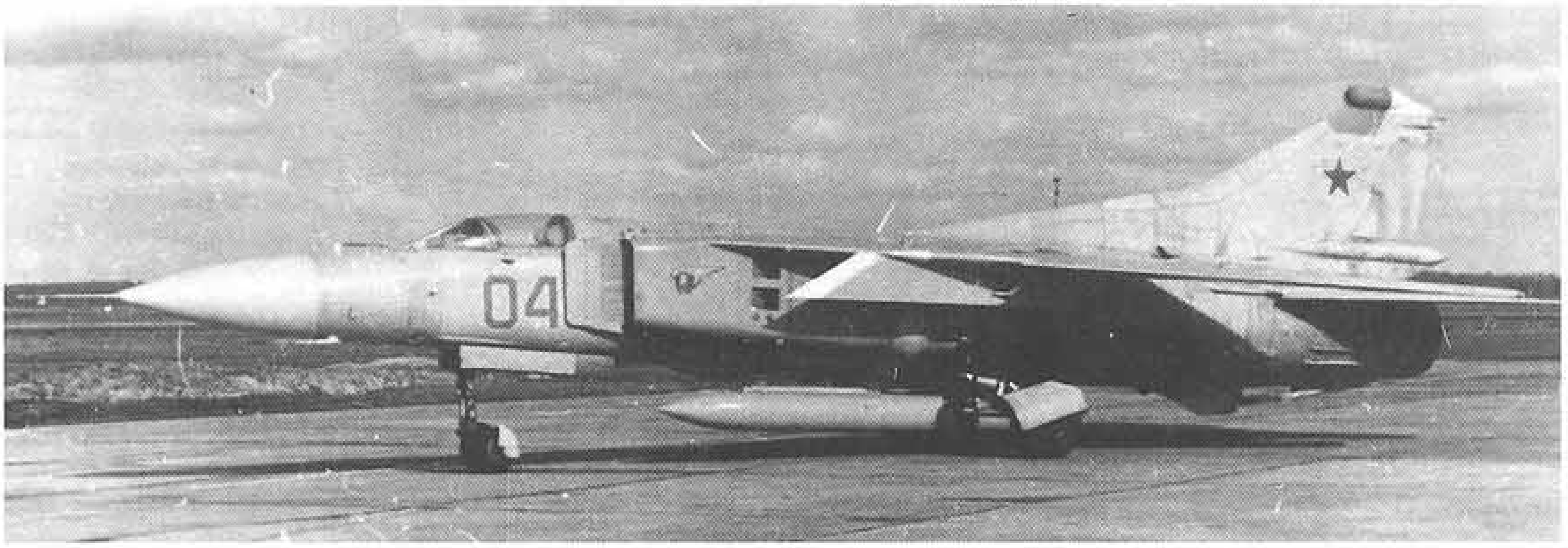
The wing intended for the MiG-23M was called 'Third Edition', or 'Edition 1972'. It combined the increased chord and large dogtooth with droop flaps, now in four sections and over the outer leading edge only. While this was being tested, the wing carry-through box (Tank 2) was redesigned to increase its strength and enable the aircraft to be cleared to a combat load factor of 8 up to Mach 0.85 (wings at 45°), and to 7 at Mach numbers higher than this. The initial production MiG-23M had the leading-edge flaps omitted in order to meet this strength requirement. Subsequent batches did have the Type 3 wing, with droop flaps set to two positions only, 0° for flight and 19° for takeoff and landing.

In the same way, the S-23 fire-control system was improved in the course of production by incorporating three successive types of radar. Most MiG-23Ms were originally fitted with *Sapfir-23*, which was matched to the R-23R missile and supplied the ASP-23D sight display. Range against a tail-on MiG-21 was about 55km (34 miles), with lock-on at 35km (22 miles). Later aircraft were fitted with the S-23D (*dorabotannyi*, upgraded), and the ultimate installation was the S-23D-III, with better discrimination and resistance to countermeasures. The radars of some earlier aircraft were brought up to S-23D-III standard. Thus, MiG-23M fighters could carry and guide the production R-23R missile, which had been specially designed for it.

Other weapons included the R-23T, all versions of R-3 (K-13), the R-60 (carried in pairs on each fuselage pylon), all Frontal Aviation rocket launchers, S-24 rockets, bombs up to FAB-1,000 (2,205lb) to a total mass of



Prototype MiG-23M, with R-23R and R-60 missiles. (OKB)



Experimental MiG-23M at LII with fin camera to film missiles launched from new pylons. (Yefim Gordon archive)

2,000kg, and other stores which later included surface-attack missiles. As before, the GSh-23L gun and its 200-round magazine were mounted on a quick-change tray similar in principle to that of the MiG-15.

The seat was the KM-1, which in many aircraft was later replaced by the KM-1M and zero/zero KM-3. The KP-27M oxygen system was fitted. Tank 4 in the rear fuselage was instrumental in raising internal fuel capacity to 4,700 litres (1,034gal), and for ferrying it was possible to use an 800lit centreline tank and a 490lit tank on each glove pylon. The water-injection tank was retained, for use at takeoff.

The autopilot was the SAU-23A, with sweep-angle, pitot pressure and the nose q-sensor all fed to an ARZ-1A feel computer governing the pitch channel. All MiG-23Ms were fitted with the TP-23 IR gondola. The vhf radio was the R-832M, the uhf the RSBN-2S, the tactical navigation system the *Polyot*-1L-23, the radio compass the ARK-15, the air/surface control receiver the *Lazur*-SM, the marker receiver the MRP-56P, the radar altimeter an RV-4, the ATC/SIF responder the SO-69 with an antenna beside the IR gondola, the IFF the SRO-2M, the RWR the *Sirena*-3M and the internal ECM the newly developed *Reper*-N (meaning a benchmark).

The first MiG-23M was flown by Fedotov in June 1972. Together with the simplified MiG-23MF and MS export versions this subfamily remained in production until 1977, and accounted for the major part of the 4,278 single-seat MiG-23s built at Moscow's *Znamya Truda* plant. The ASCC name was 'Flogger-B'.

Span as 23-11; length 16.71m (54ft 9⅞in), (excluding PVD) 15.73m (51ft 7¼in); wing area (16°) 37.35sq m (402sq ft), (72°) 34.16sq m (367.7sq ft).

Weight empty 10,869kg (23,962lb); internal fuel 3,800kg (8,377lb); weight loaded 15,750kg (34,722lb); maximum takeoff 20,670kg (45,569lb).

IAS limit (16°) 800km/h (497mph), (72°) 1,200km/h (746mph); maximum speed (72°) 2,490km/h (1,547mph, Mach 2.34) at 12,500m (41,010ft); initial climb 210m/s (40,354ft/min); climb to 11,000m (36,090ft) 1.4min; service ceiling 17,500m (57,415ft); range (16°, clean) 2,200km (1,370 miles), (three tanks) 3,300km (2,050 miles); takeoff run 580m (1,900ft); landing speed 265km/h (165mph); landing run 755m (2,477ft).

MiG-23MF

This was the version of MiG-23M for export to air forces in the Warsaw Pact. Among the minor modifications were the fitting of a different rudder yaw damper, and the ATC/SIF transponder was changed from the SO-69 to the SOD-57M, which was considered more appropriate to the operating airspace. Data unchanged.

MiG-23MS

This was the version of MiG-23M for export to non-Warsaw Pact air forces. As its small radome showed, the S-23D radar was replaced by the much less powerful *Sapfir*-21, so apart from having somewhat better range and endurance the only advantage of this aircraft over the later MiG-21s was that it could fire the IR-homing R-23T, as well as the simple R-3 variants. Some, but not all, were further downgraded by having the low-powered R-27F2S-300 engine. Customers included Afghanistan, Algeria, Angola, Cuba, Egypt, Ethiopia, India, Iraq, Libya, South Yemen, Syria and Vietnam, with customer paint schemes.

The MiG-23MS was first delivered in 1973. Several early examples crashed because of failure of either the wing box/pivot or the sweep drive. Moreover, most of the examples seen by Western observers were badly flown by unskilled pilots of foreign air forces, causing the MiG-23 to be seriously undervalued by analysts. The visibly different radar resulted in the ASCC name 'Flogger-E'. Specification unchanged.

MiG-23ML, 23-12

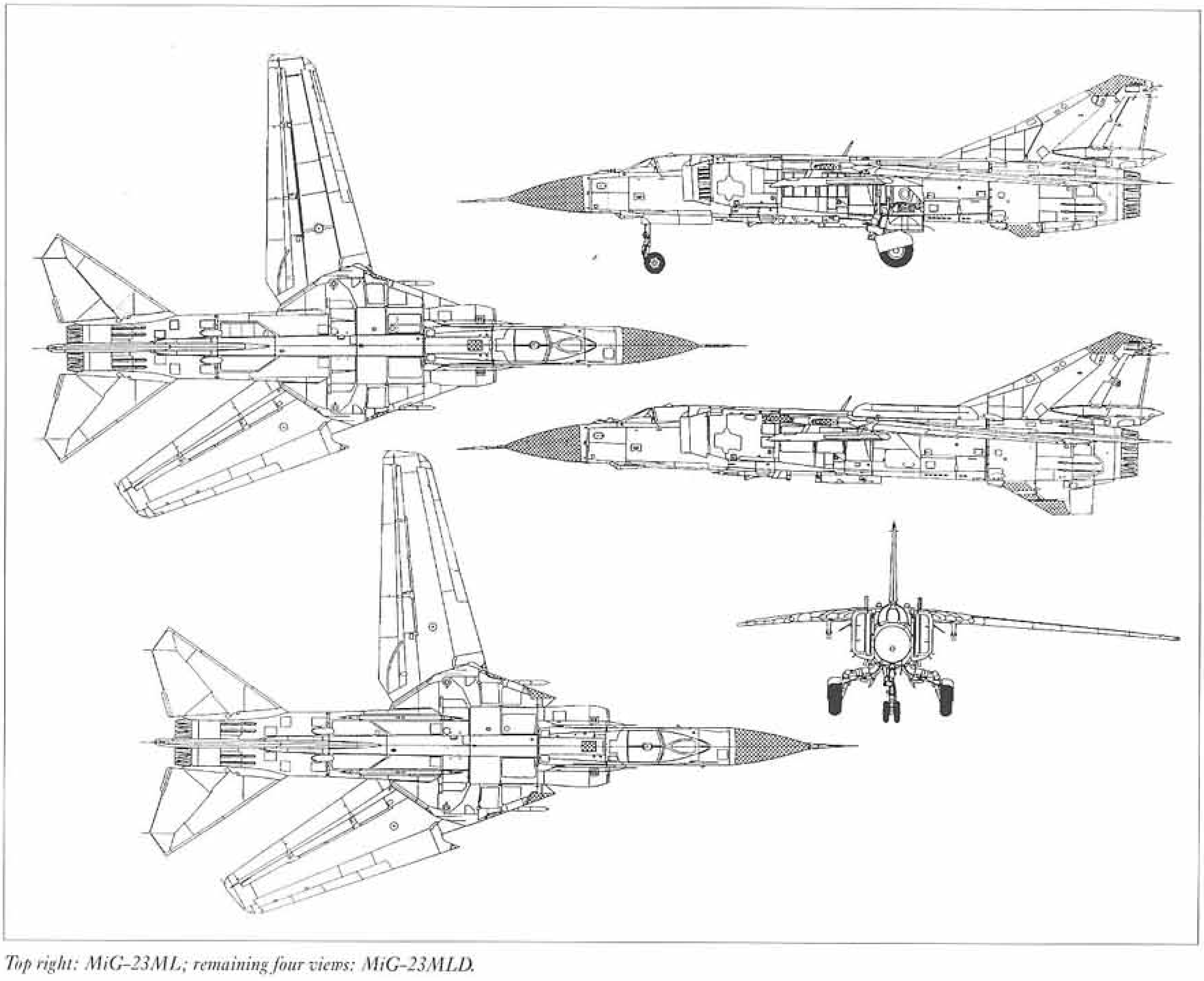
Whereas previous single-seat versions had been multirole aircraft, this variant was specifically developed as a Frontal Aviation fighter, with a designation derived from *lyogkiy* (lightened). The most fundamental differences were careful reduction in weight throughout, restressing of the entire structure so that 8.5g could actually be used safely, and installation of yet another new Khachaturov engine, the R-35-300, with maximum dry and afterburning ratings of 8,550kg and 13,000kg (18,849lb and 28,660lb), respectively. This engine had a gas-turbine starter, with air intake and exhaust doors near the left front of the ventral fin which closed automatically when the landing gear was retracted.

The fire-control system was redesigned for use only against forward-sector aerial targets, and designated S-23ML. Its HUD-sight was the ASP-17ML, to which were fed images from the significantly lighter *Sapfir*-23ML radar and TP-23ML IR search/tracker with increased-aperture optics in an enlarged gondola. The radar slightly reduced fuselage length, and to balance its reduced mass and changed radome aerody-

Prototype MiG-23ML. (OKB)

namics the dorsal fin was replaced by an almost imperceptible kink in the fin leading edge, and the trailing edge of the ventral fin was moved forwards.

Another important modification was the omission of Tank 4 in the rear fuselage, reducing fuel capacity by 390kg (860lb). The two inboard sections of the trailing-edge flap were combined, and the leading-edge flaps were made lighter yet more rigid. The main landing-gear units were made 175mm (6.9in) longer, with 840 × 290mm tyres inflated to 12±0.5ata (176lb/sq in), and the nose unit was strengthened and fitted with 570 × 140mm tubed (previously tubeless) tyres inflated to 7±0.5ata (103lb/sq in).



Top right: MiG-23ML; remaining four views: MiG-23MLD.

The mudguard was later removed (this became standard on later versions).

Less obvious modifications included fitting the SAU-23AM autopilot, linked to the *Polyot*-2L-23 precision navigation system, with input from the new *Lazur*-SML beam/beacon receiver. Some aircraft were built with SRO-2, but the standard IFF system was the SRZO, with a blade antenna ahead of the windscreen and inside dielectric panels forming the outer section of the leading edge of the wing glove. These antennas were protected from impact damage by making the tips of the outer-wing dog-teeth of softer material.

Other new avionics items included the R-862 uhf, the ARK-19 radio compass and the A-031 radar altimeter. The angle of attack (AOA) vanes and air-data probes were augmented and repositioned, with a small AOA weathercock on each side of the fuselage approximately in line with the windscreen. Small vortex generators, called *metallicheskiy ugolok* (angle irons), were added above the wingtips, ahead of the outer part of the outermost trailing-edge flap and ahead of the upper half of the rudder.

Air-combat armament was upgraded by fitting tandem hardpoints under the fuselage centreline, which together with the attachments under the inlet ducts and gloves made it possible to carry (for example) six R-60 or R-60M plus two R-23R, R-23T, R-24R or R-24T missiles simultaneously. Alternatively the centreline gun could be partnered by two more, with 250 rounds each, in UPK-23-250 pods hung on the glove pylons.

The 23-12 prototype completed factory and State testing in 1975, and the MiG-23ML was produced by the MMZ plant between 1976 and 1981. It was considered an excellent aircraft, with acceleration from low speeds to above Mach 1 better than the F/A-18. In 1978 a team of six from Kubinka visited Finland and France. For security reasons the IR gondola was removed, and Western analysts said 'This is a special version modified for an aerobatic team'. Export variants were sold to Czechoslovakia, the German Democratic Republic, Iraq, North Korea, South Yemen and Syria. From 1981 all in Frontal Aviation service were brought up to MLD standard (*see* later). The ASCC name was 'Flogger-G'.

Dimensions unchanged.

Weight empty 9,900kg (21,825lb); internal fuel 3,310kg (7,297lb); weight loaded 14,700kg (32,407lb); maximum takeoff weight 17,800kg (39,242lb).

Maximum speed at low level (16°) 940km/h (584mph), (72°) 1,350km/h (839mph, Mach 1.1), at high altitude (72°) 2,500km/h (1,553mph, Mach 2.35); initial rate of climb 240m/s (47,244ft/min); service ceiling 18,500m (60,700ft); range (16°, clean) 1,950km (1,212 miles), (three tanks) 2,820km (1,752 miles); takeoff run 400m (1,312ft); landing speed 255km/h (158mph); landing run 700m (2,297ft) with parabrake.

MiG-23MLA

Dating from 1977, this improved frontal fighter was fitted with a new radar called *Ametist* (Amethyst), an alternative designation being *Sapfir*-23MLA. Equipment and armament were otherwise the same as the MiG-23ML.

MiG-23P, 23-14

Also dating from 1977, this was the only MiG-23 variant specifically developed as an interceptor, for the IA-PVO. It was based on the MiG-23ML, and retained the same *Sapfir*-23ML radar, R-862 uhf, ARK-19 radio compass and A-031 radar altimeter. The sensitive TP-26 IR installation had a range against typical sources increased from 35km to 60km (37 miles). The most important addition was a secure digital data-link and navigation computer linked with the *Vozdukh* GCI (ground control of interception) network. Small antennas were added on the flank of each engine inlet duct. Through the SAU-23AM autopilot this steered the aircraft to effect interceptions, giving the pilot signals on when to go into afterburner and when to select and fire a missile or search ahead for the target before opening fire with the gun.

Factory testing was completed in August 1978. By this time the MiG-23P was in service, though NII-VVS testing did not take place until 3 March 1981, being completed on 29 December 1982. By this time most MiG-23Ps were being modified to MiG-23MLD standard. No ASCC name is known. Data as MiG-23ML.

MiG-23MLD, 23-18

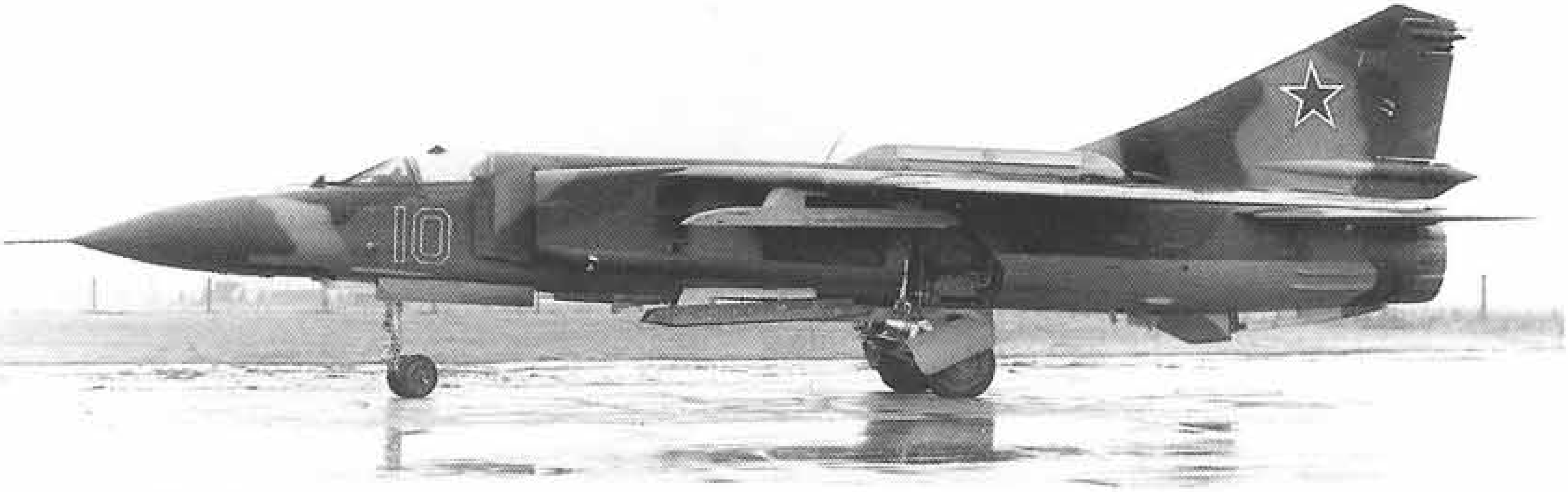
Dating from 1984, this was the definitive MiG-23 frontal fighter version. None were built new; all were created by modifying existing MiG-23ML fighters and MiG-23P interceptors. The designation again stemmed from *dorabotannyi*, upgraded.

The most basic change was that the 'Fourth Edition' wing was fitted. The modifications replaced the SOUA control system by the SOS-3-4, which sensed not only q (dynamic pressure) but also angle of attack, using the small weathercock vanes on each side of the forward fuselage. This automatically scheduled the leading-edge flaps to droop to the increased angle of 20° as soon as AOA reached 10° during combat manoeuvres at an IAS below 900km/h (559mph), with the wings at the new intermediate setting of 33° (instead of 45°). If the pilot selected sweepback beyond 33° the commanded leading-edge flap angle was progressively reduced, reaching zero at a sweep angle of 72°.

Small but extremely powerful aerodynamic changes were made to enhance combat manoeuvrability still further. The inboard leading edge of the fixed glove section was removed and replaced by a reverse-angle (forwards swept) dielectric antenna for an L006 command-guidance transmitter. At high angles of attack these 'claws' generated powerful vortices, which were augmented by small sharp-edged plates added on each side at the root of the nose probe. Following a number of pilot errors, an additional warning system was added to prevent (for example) speed being reduced with wings at 72°.

The engine was the R-35F-300, with unchanged ratings. The General and Utility hydraulic systems were improved. Provision was made for a greater variety of loads on the four fuselage pylons, including three designs of tank. Provision was also made (but seldom used) for adding additional pylons under the outer wings, which swivelled to keep them always aligned with the slipstream. Maximum external weapon load was increased to 4,500kg (9,921lb).

Above the fuselage behind the canopy the doors and hatches were rearranged, with the air-conditioning inlets and exhaust relocated and the avionics racking accessed by hatches on each side. The elevator trimmer switch was moved from the coaming to the stick. The group of nine items (sensors, antennas, static discharger and light) at the top of the fin was again modified. The *Sirena*-3M warning system was connected to BVP 50-60 chaff/flare dispensers scabbed on above the fuselage, on each side near



MiG-23MLD, with BVP-50-60 dispensers. (photograph by Yefim Gordon)

the wing trailing edge. When unloaded, these dispensers were covered by fairing caps. Behind the ventral fin was added a hatch giving access to radio cables. A novel addition was an air-combat simulator enabling the pilot to intercept and shoot down synthetic targets projected on his sight.

MiG-23MLD conversions were produced from 1984, and a few are still operational. New missiles introduced during their active service were the R-27 and R-73. They were one of the most successful aircraft in Afghanistan, and were considered the only MiG-23 variant capable of beating the F-16A and the F/A-18A. The 'claw' wing root resulted in a new ASCC name, 'Flogger-K'.

Dimensions unchanged.

Weight empty 10,200kg (22,487lb); internal fuel 3,310kg (7,297lb); weight loaded 14,840kg (32,716lb); maximum takeoff weight 18,400kg (40,564lb).

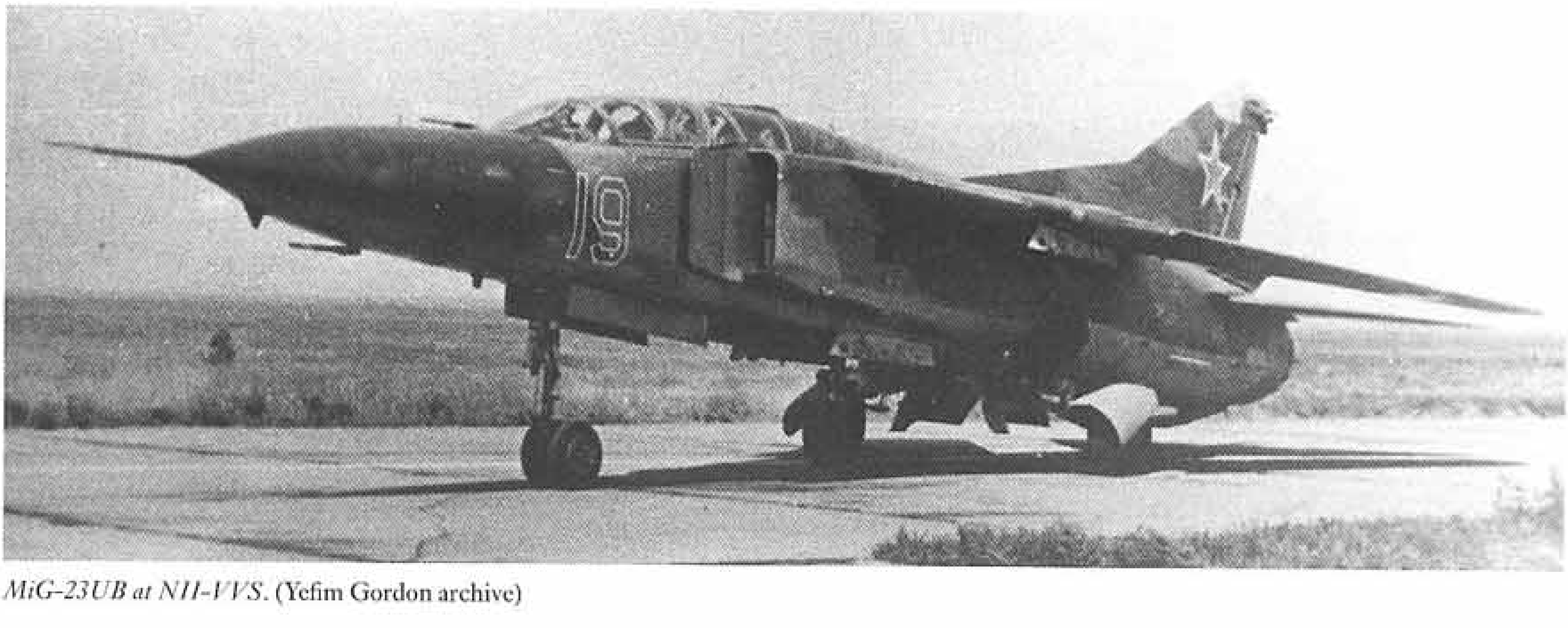
Maximum speed (16°) 940km/h (584mph), (72°) 1,400km/h (870mph, Mach 1.14) at sea level, 2,500km/h (1,553mph, Mach 2.35) at 13,000m (42,651ft); initial rate of climb 230m/s (45,276ft/min); service ceiling 18,600m (61,024ft); range (clean) 1,800km (1,118 miles), (three tanks) 2,600km (1,616 miles); takeoff run 500m (1,640ft); landing speed 240km/h (149mph); landing run 750m (2,461ft) with parabrake

MiG-23UB, 23-51

In contrast to the MiG-19 and MiG-21 programmes, a dual-control version of the MiG-23 was agreed by the Council of Ministers as early as 17 November 1967. Two prototypes were built at the OKB in parallel with the MiG-23S, which was used as the basis, but with the structure upgraded to a load factor of 7. The designation meant *uchebno boyevoi* (fighting instruction), indicating that the two-seater was to be used for weapon training as well as conversion to type.

Features included the R-27F2M-300 engine and 'Third Edition' wing. The main modification was to redesign the fuselage between Frames 8 and 18 to accommodate the rear cockpit, at a higher level to give the instructor a better forward view. Both cockpits had KM-1 seats (H=0, V=130-1,250km/h) with the same central control. The instructor could disconnect the pupil's flight controls and could also initiate the ejection sequence, but the pupil could not eject the instructor. The front canopy was enlarged, sloping up to hinge on a crash arch with side windows between the cockpits. From this a blind-flying hood could be pulled forwards on side rails. The pupil had no rear-view mirror, but the rear canopy was fitted with a 460mm (18in) periscope which could be extended from the metal centre of the roof to improve view ahead.

The rear cockpit required the main equipment bay (air conditioning, emergency hydraulic turbopump and other items) to be moved back into the bay formerly occupied by Tank 1. This tank was reduced in capacity, but a 470lit (103gal) tank was added in the rear fuselage which actually resulted in internal fuel capacity being greater



MiG-23UB at NII-VVS. (Yefim Gordon archive) than in the single-seaters. In addition to the usual provision for centreline and glove tanks, the series aircraft could also be fitted with fixed tank pylons under the outer wings at 16° sweep for ferrying.

The first 23-51 prototype, callsign 'Blue 251', was fitted with *Sapfir*-21 (MiG-21 type) radar, but in series aircraft this was replaced by ballast. Other avionics included SAU-23B flight control with ARZ-1A artificial feel on all axes, with the SOUA high-authority AOA limiter incorporating the UUA-1 indicator, SUA-1 warning and RIS stick-shaker. The flight-control system was also linked to the *Polyot*-11-23 navigation system comprising RSBN-6S homing/landing, SKV-2N2 vertical-gyro heading and DV-10 and DV-30 beacon transmitters. Other standard items included the ARK-10 radio compass, RV-5 radar altimeter, SRO-2 IFF, SOD or SO-69 ATC/SIF, *Sirena*-3 RWR feeding the SORT central alarm display and a target-identification system.

The cockpits were linked by the SPU-9 intercom, with an MS-61 CVR (cockpit voice recorder). The pupil had an ASP-PFD-21 sight, without radar ranging. He could train with the GSh-23L with 200 rounds, and with R-3R and R-3S missiles, bombs and other stores on the two fuselage and two glove pylons. The series aircraft also had provision for carrying and firing the Kh-23 (R-23R) attack missile using an external guidance pod.

Developing the trainer proved to be a major task, and 'Blue 251' was not flown by M M Komarov until 11 May 1969. Factory testing on the two prototypes was done by Komarov and Ostapenko, followed by NII-VVS trials in winter 1969–70. By this time tooling was in place at the Irkutsk factory, formerly No. 125. Here 769 aircraft were built by 1978. This total included a small number of MiG-23UM aircraft with improved equipment. The two-seater served with the FA, IA-PVO and almost all MiG-23 export customers. The ASCC name was 'Flogger-C'.

Dimensions unchanged.

Weight empty 10,505kg (23,159lb); internal fuel 4,000kg (8,818lb); weight loaded (normal) 15,740kg (34,700lb), (maximum) 18,000kg (39,683lb).

Maximum speed (clean, 16°) 800km/h (497mph), (72°) 1,200km/h (746mph) at sea level, 2,445km/h (1,519mph, Mach 2.3); climb to 11,000m (36,089ft) 1.4min; service ceiling 15,800m (51,840ft); range 1,950km (1,212 miles), (three tanks) 3,000km (1,864 miles); takeoff run 600m (1,969ft); landing speed 235km/h (146mph); landing run 750m (2,460ft).

MiG-23P project

This designation was reused in the late 1960s for a proposed carrier-based version for the A-VMF. Intended primarily as a fighter, it would have had a long-stroke main landing gear with smaller high-pressure tyres, an arrester hook, no braking parachute and possibly provision for oversweeping the wings to reduce spotting factor (space taken up on deck). The Defence Ministry planned to use this version either alongside or instead of a naval version of the Su-24. All that happened was that a hooked version of the MiG-27 was tested from the simulated carrier on the airfield at Saki. No ASCC name is known.

MiG-27Sh project

In 1969, in response to a Frontal Aviation requirement, the OKB began to study aircraft for attack on surface targets and other operations at low and medium altitudes. Initially the studies focused on subsonic 'jet *shturmovik*' (armoured attacker) aircraft, as well as this transonic fixed-wing project with a MiG-21 tail and fixed-geometry lateral inlets. This was eventually rejected in favour of the *Izdeliye* 32-24.

MiG-23B, 32-24

In May 1969 the idea of a new-design attack aircraft was abandoned, and the decision was taken to develop a supersonic aircraft based on the MiG-23S. This was considered to be more survivable in hostile airspace, more versatile in being able to undertake fighter as well as bomber missions, and better able to defend itself against intercepting aircraft.

The most basic change was to replace the radar by a totally different navigation/attack system housed in a forward fuselage redesigned back to Frame 8. This new nose section had an almost untapered horizontal underside, but the top tapered sharply from the windscreen to the pointed tip. The cross-section was an increasingly flattened oval. Called *utkanos* (duck nose), it gave the pilot the best possible forward view. His KM seat was raised and the canopy and, especially, the windscreen were modified to improve field of view even further. The windscreen panels were made to resist 20mm projectiles, and removing the 498kg (1,098lb) radar allowed armour to be scabbed on each side of the fuselage skin.

The engine was changed to the Lyul'ka AL-21F-3 (*Izdeliye* 89), rated at 8,000kg (17,637lb) dry and 11,200kg (24,691lb) with maximum afterburner. This engine was not only more powerful than the engine of the MiG-23S but it was already in production for the Su-17M and Su-24 used for the same missions.

To enable the aircraft to mount sustained operations from unpaved front-line airstrips the landing gear was strengthened, hydraulic lines protected and the mainwheels replaced by a new pattern with 12-ply tubeless 840 × 360mm tyres, inflated to only 10±0.5kg/sq cm (142lb/sq in). These caused significant lateral bulges to the fuselage and wheel-bay doors. Track was increased to 2.728m (8ft 11½in) and wheelbase to 5.991m (19ft 7⅞in).

Apart from increasing the boundary-layer gap from 55 to 80mm (3.15in), the engine air inlets were not modified, though the engine bay and much of the rear fuselage had to be considerably altered. By adding a Tank 1A immediately behind the cockpit internal fuel capacity was significantly increased, to 5,380 litres (1,183.5gal), and all tanks were protected. They were also fitted with an inert-gas (nitrogen) system to prevent battle damage causing explosions, though in normal peacetime operation the tanks were pressurized by cooled engine bleed air. The wing was 'First Edition', and the tail was almost identical to that of the MiG-23S.

Instead of the radar the nose housed the racking for the PrNK-23S *Sokol* (falcon) navigation/attack system. This comprised a DISS-7 four-beam doppler radar, twin-gyro platform, RV-5R radar altimeter and V-144 computer. Other avionics included the SAU-23B autopilot, R-802G, R-832M and R-855UM radio, RSBN-6S tactical navigation system, ARK-15M radio compass, MRP-56P (A-611) marker receiver, SOD-57M ATC/SIF transponder, RI-65B tape recorder and SZM radar warning system.

The MiG-23B was designed to make any kind of attack with nuclear or conventional bombs, rockets or the internal GSh-23L gun with 200 rounds, installed as in the MiG-23S.

For gunnery the pilot used the ASP-17B optical sight, but for bombing he used the *Sokol* system in conjunction with a sight designated RBK-3. Bombs could be released in level flight at any altitude, or in steep dive attacks or in an over-the-shoulder toss.

There were the usual five hardpoints for stores: a centreline attachment for a tank or any of five yields of TN (tactical nuclear) bomb, two racks under the inlet ducts, and two under the gloves. Within the overall limit of 3,000kg (6,614lb) it was possible to carry any combination of Frontal Aviation weapons.

The prototype, callsign '321', was first flown by Ostapenko on 20 August 1970. Together with the second aircraft, '322', it passed factory and State testing remarkably quickly, and the MiG-23B entered series production at the *Znamya Truda* factory in 1971. However, only twenty-four had been completed when it was replaced on the assembly line by the MiG-23BN. The ASCC name was 'Flogger-F'.

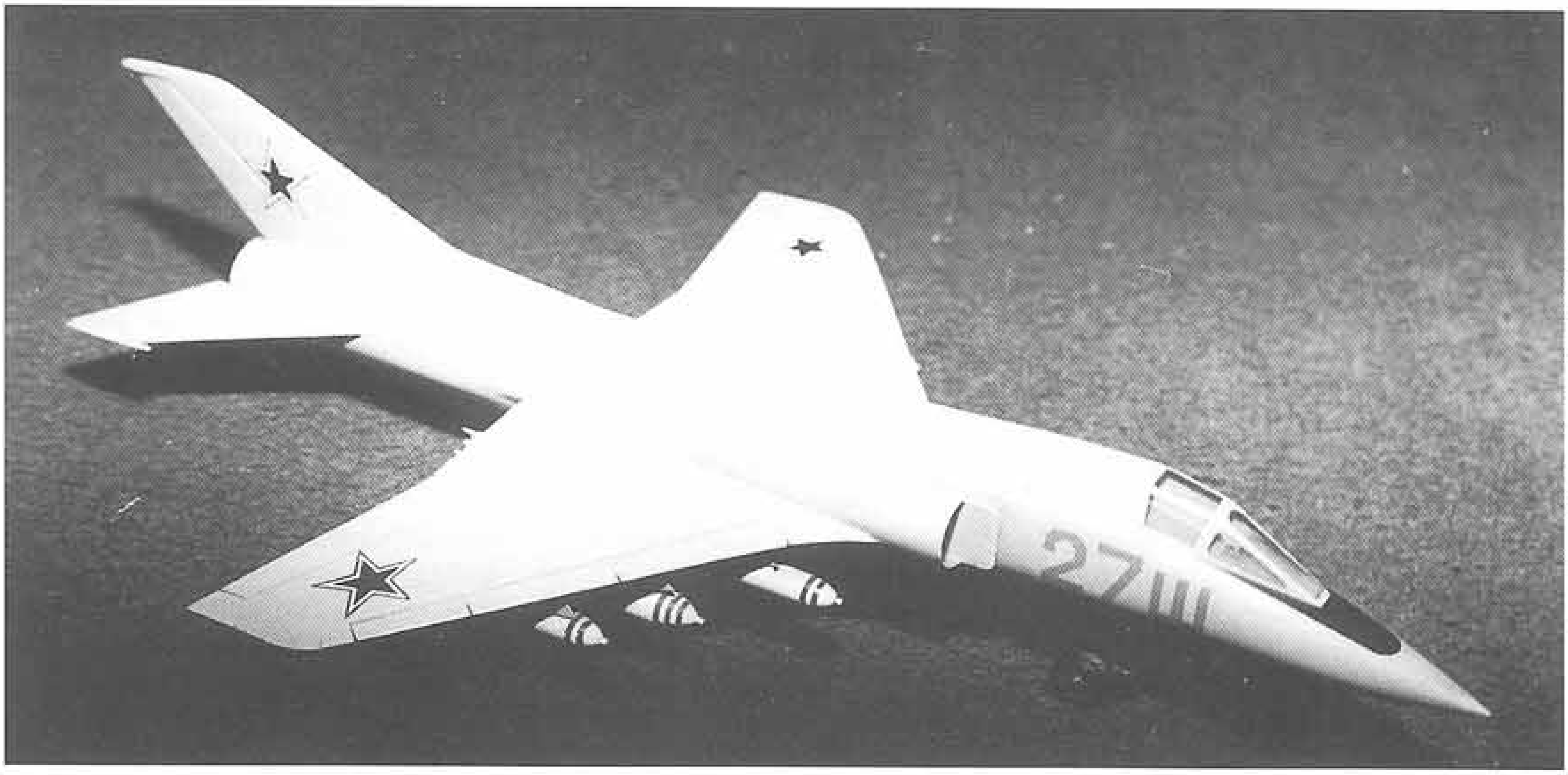
Dimensions unchanged from 23-11, except for reduced length 16.7m (54ft 9½in), (excluding boom) 15.349m (50ft 4¼in).

Weight empty 10,020kg (22,090lb); internal fuel 4,500kg (9,921lb); weight loaded 15,600kg (34,392lb); maximum takeoff weight 18,600kg (41,005lb).

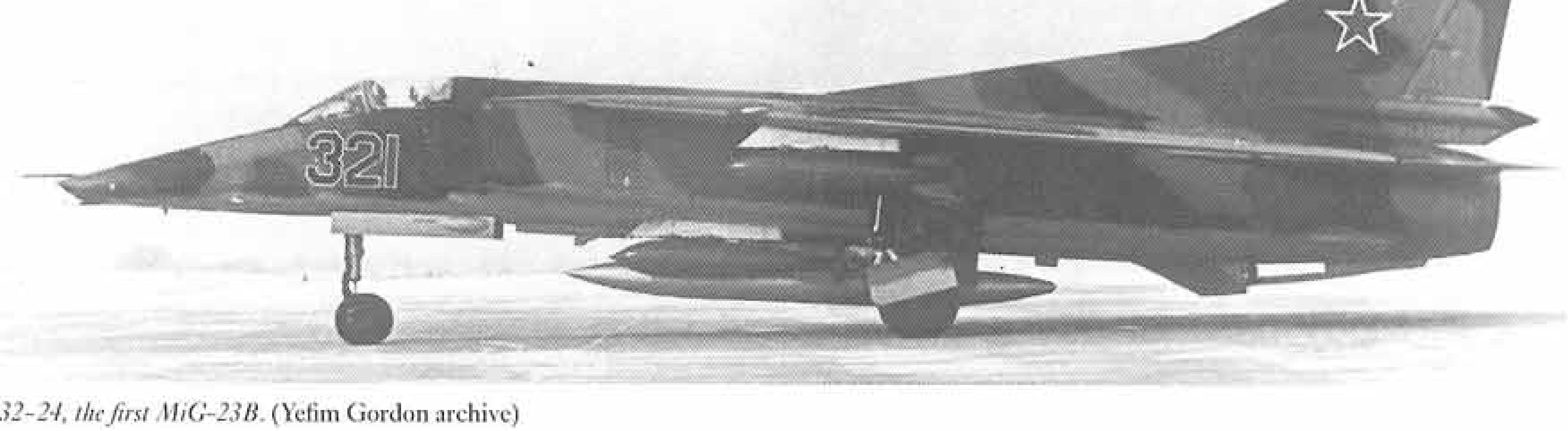
Maximum speed (72°) 1,350km/h (839mph) at sea level, 1,800km/h (1,118mph, Mach 1.695) at 8,000m (26,246ft) and above; (16°) 935km/h (581mph) at 3,500m (11,482ft); climb to 11,000m (36,089ft) 1.7min; service ceiling 16,000m (52,493ft); combat radius (hi-lo-hi with 1,000kg bomb load) 850km (528 miles); takeoff run (no a.t.o.) 950m (3,117ft); landing speed 240km/h (149mph); landing run 900m (2,953ft).

MiG-23BN, 32-23

The most obvious external difference between this aircraft and the interim MiG-23B was the introduction of the 'Third Edition' wing, with a prominent dogtooth, increased area and two-position leading-edge flap in four sections. Less obvious was a return to the outstanding R-29 engine, but in a new version simplified for the attack mission. Designated R-29B-300, it had a shorter nozzle with only two positions, closed (maximum thrust 8,000kg, 17,637lb) and open (in afterburner, maximum thrust 11,500kg, 25,353lb). This engine was slightly shorter, slimmer and lighter than the AL-21F-3, and being a two-shaft engine it responded faster to pilot demand. A third modification was to restress the airframe to a load factor of 7.5.



MiG-27Sh project model. (photograph by Yefim Gordon)



32-24, the first MiG-23B. (Yefim Gordon archive)

The navigational/attack system was upgraded to the *Sokol*-23N standard. Among the additions or improvements were the *Fon* (background) laser ranger and the *Delta*-N, -NM or -NG command transmitter for the Kh-23 attack missile. The usual missile was the Kh-23M, carried on a glove pylon. Another upgrade was to add a pylon projecting on each side of the fuselage behind the main landing gear. These could carry FAB-500 (1,102lb) bombs, and could also be used to attach SU-1500 or SPRD-99 assisted takeoff rockets.

In 1974–80 the *Znamya Truda* factory made a large number of MiG-23BN aircraft. Customers included Afghanistan, Algeria, Angola, Bulgaria, Cuba, Czechoslovakia, the German Democratic Republic, Egypt, Ethiopia, Hungary, India, Iran, Iraq, Libya, Nigeria, North Korea, Poland, Syria, South Yemen and Vietnam. Examples saw action in Afghanistan, Angola, Libya and on both sides in the Iran–Iraq war, in which the Iraqi aircraft had Dassault nonretractable flight-refuelling probes. The ASCC name was 'Flogger-H'. Data essentially unchanged from MiG-23B except normal loaded weight increased from 15,600 to 16,450kg (36,265lb).

MiG-23BM, MiG-27, 32-25

With the *Izdeliye* 32-25 the OKB ignored the fighter mission in order to produce an uncompromised frontal attack aircraft. New features comprised simplified inlets to the R-29B-300 engine, a new wing-sweep control system and a modified suite of avionics. The emphasis was on creating an aircraft tailored solely to the attack mission, as simple and inexpensive as possible.

This variant was the first to have simplified engine inlets. These were merely the front ends of the rectangular ducts, with bulged sides and a vertical leading edge. On the inner side was a short wall, 80mm (3⅛in) away from the fuselage as before, with no hinged section and no perforations. The two suck-in auxiliary inlets on the outer side of the duct were retained. These simplified inlets saved 300kg (661lb) in weight, and required little maintenance. The penalty was a reduction in maximum speed from Mach 2.35 to 1.7, but in fact on ground-attack missions aircraft almost never exceeded Mach 1. Accordingly, the inlets had a large lip radius, which gave better pressure recovery than a sharp-edged inlet suitable for supersonic flight. The lip was steel, and unpainted.

The wing was 'Third Edition', but with infinitely variable, rapid-action sweep control to preserve longitudinal stability according to IAS and centre of gravity position. In a low-level mission turbulence was minimized by sweeping the wings fully. The normal flight setting was 45°, unless underwing 790lit drop tanks were carried, when the wings were locked at the forward position, with the leading edge at 18°40′ and the trailing edge at 2°. In the maximum-sweep position the leading-edge angle was 74°40′ and the trailing edge angle 58°.

As in earlier attack versions, harsh manoeuvres at low level, and proximity of the sweep drive to the steel Tank 2 forming the wing centre box, caused deformation and leakage. Difficulties were also experienced with drop tanks. Another problem was that if a spin became established, no recovery was possible at any wing position. Design load factor was 7, but this was seldom attempted and could not be sustained. Limiting flap IAS was 450km/h (280mph). Below this they could be opened to 15° for the approach, and near the runway they were opened to the maximum of 50°. Again as in the MiG-23, a number of aircraft were lost because of failure of flap synchronization.

To enable the MiG-23BM to operate from unpaved airstrips the tyres were made wider and their pressure reduced from 12.5 to 11kg/sq cm (156lb/sq in). The nosewheels were fitted with tubed tyres 570 × 140mm, and the main tyres were tubeless and size 840 × 360mm (actual outer dimensions 810 × 35 mm). Each main tyre weighed 44kg (97lb), much heavier than any previous MiG tyre apart from the MiG-25, whose main tyres weighed 89kg (196lb). Following common Frontal Aviation practice, the wheels were painted green. The mainwheels were type KT-163, similar to those of the Su-25 but without a brake cooling fan. The main legs were strengthened, and their shock-absorber overload valves deleted. The nosewheels were fitted with a mudguard, but this did not protect the engine from foreign-object damage and by 1986 most had been removed. The FOD problem and escalating takeoff weight made the objective of operating from rough front-line airstrips unattainable, except in emergency.

Normal internal fuel capacity was increased to 5,400 litres (1,188gal), by Tank 1A behind the cockpit. Alongside the engine was a 2lit (6.16gal) tank of injection water. The 'duck-nose' carried the same PVD as fitted to the MiG-23B and BN, and the same q-feel probe to the right of the windscreen.

The PrNK-23 navigation/attack complex included the SAU-1 automatic flight-control system, linked through the new KN-23 analog navigation computer, and incorporating the *Fon* laser. For attacks with missiles the *Delta*-2NG command link used bullet-shaped antennas above the glove pylons. Other avionics comprised the SUA-1 AOA (angle of attack) warning system complete with a stick-shaker; an SG-1 RWR (radar warning receiver) and IR warning feeding an RI-65 sixteen-channel display and aural warning indicator; either SRZO or SRO-1P IFF with blade antennas; RV-5R or RV-10 radar altimeters; SO-69 ATC/SIF transponder; SP-50 ILS; and standard uhf/vhf radio.

A major upgrade was to fit a completely new and very powerful gun, the GSh-6-30. This was a six-barrel weapon capable of firing the standard high-velocity 30mm ammunition at 6,000 rounds/min. It was semi-recessed under the fuselage and fed from a 260-round magazine immediately above. This superb gun caused problems because of its power. Difficulties included jammed nose landing gear because of door distortion, breakage of the six-barrel chain drive which could damage Tank 1A fuel booster pump, fractures of Tank 1A rear wall, damage to the landing lights (retracted under the air-inlet ducts), ingestion into the engine of gun gas, and switching of the seat-arming circuit from 'fire' to 'safe' caused by recoil. In the first two years of service it was almost unknown to fire all 260 rounds without a jam, and to prevent damage the magazine was routinely loaded with 30 rounds only. All these difficulties were eventually cured, the gun soon being covered by a faired box with gas deflector vanes.

Maximum weight of dropped stores was 4,000kg (8,818lb), on seven pylons of improved designs. These were located on the centreline (plumbed for a 790lit tank), under each inlet, under each fixed glove and, with reduced fuel, on the rear fuselage. For ferry purposes 790lit (173 gal) tanks could be carried under the outer wings, locked at 16° until the tanks were dropped. Stores included all standard Frontal Aviation conventional and nuclear bombs and rocket launchers, S-24 heavy rockets, Kh-23M missiles, PLAB napalm, KMGU bomblet dispensers, SPPU-22-01 gun pods (GSh-23 with depressed barrels), or R-3 or R-60 self-defence missiles.

The MiG-23BM prototype was prepared at the OKB shop by modifying a MiG-23B. The nose was replaced, but the original inlets were left as they were, and no side armour was fitted. This aircraft was flown in 1974 by OKB pilot Valeriy Ye Menitskiy. By this time production was already beginning at Irkutsk (which many years earlier had been Factory No. 39). The production aircraft was redesignated **MiG-27**.

In 1974–77 Irkutsk produced 560 MiG-27s, all for Frontal Aviation. In early 1975 the first regiment was equipped in the German Democratic Republic, at a time when its ancestor, the MiG-23BN, was unknown in the West. Accordingly it received the earlier ASCC name of 'Flogger-D'.

Dimensions as MiG-23M ('Third Edition' wing) except length 17.076m (56ft 0¼in), (excluding PVD) 15.489m (50ft 9¾in).

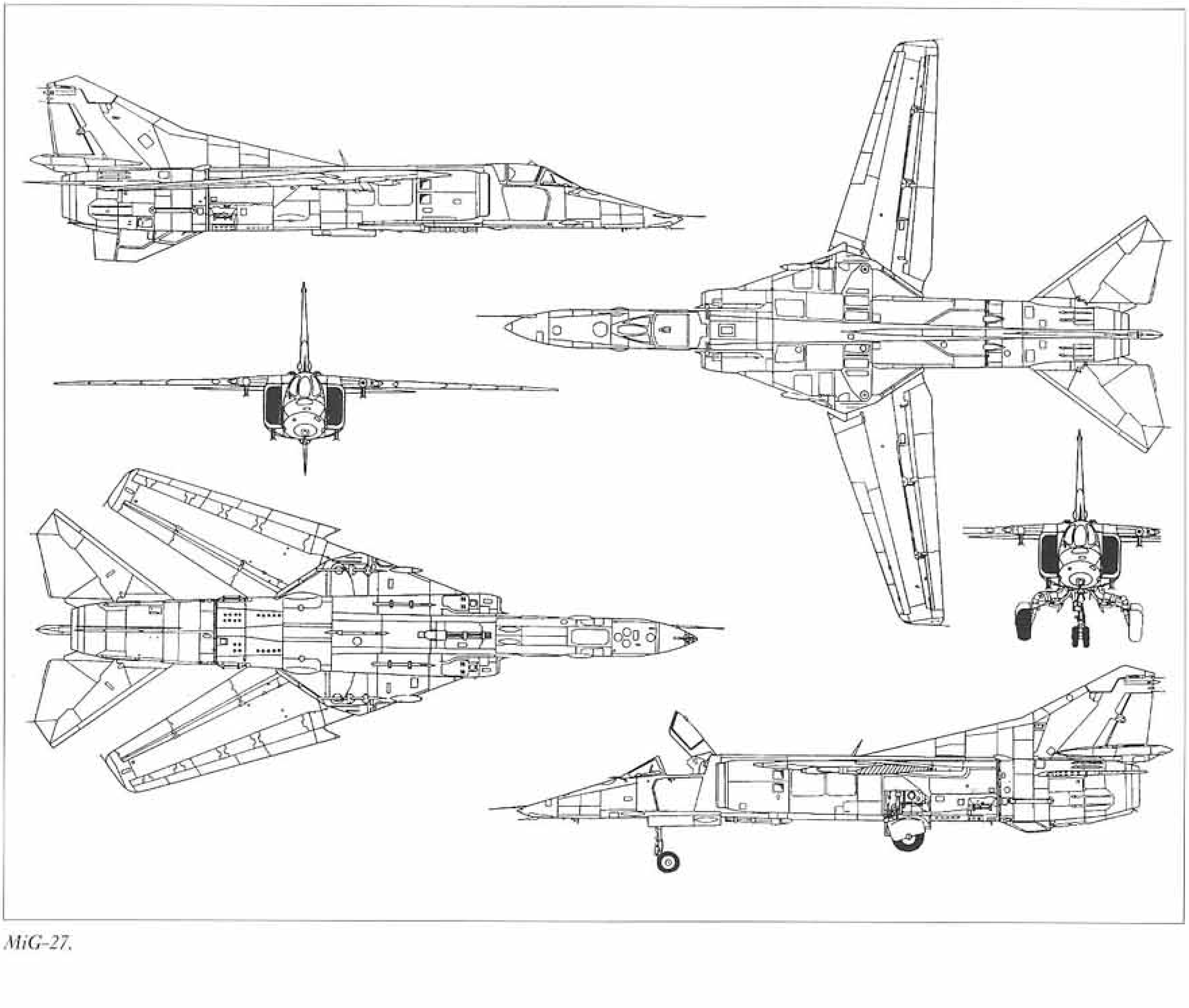
Weight empty 11,256kg (24,815lb); internal fuel 4,560kg (10,053lb); weight loaded (clean) 16,005kg (35,284lb), (maximum for unpaved strip) 18,100kg (39,903lb), (maximum) 20,300kg (44,753lb).

Maximum speed (clean, sea level) 1,350km/h (839mph, Mach 1.1), (clean, 8,000m/26,247ft) 1,885km/h (1,171mph, Mach 1.7), (maximum in service with bombs) 1,000km/h (621mph); minimum manoeuvre speed 400km/h (249mph); combat radius (lo-lo-lo, internal fuel and bombs) 200–225km (124–140 miles), (lo-lo-lo, three tanks) 540km (336 miles); takeoff run (18,100kg) 950m (3,117ft), (20,300kg) 1,190m (3,904ft); landing speed 260km/h (162mph); landing run 850m (2,788ft) with chute, 1,300m (4,265ft) without.

MiG-23BK, 32-26

This was the final attack version of the MiG-23, because from 1974 it was evident that the MiG-23BM (MiG-27) was more cost-effective in front-line operations. It differed from the MiG-23BM only in having additional or upgraded equipment. The PrNK-23K fire control was enhanced in computing capability to handle a wider range of attack profiles, speeds and heights. It could operate in two previously unavailable modes: PMS, for gun, rocket and bomb attacks while making evasive manoeuvres, and PKS, making attacks at night or in bad weather on targets having previously programmed coordinates. The aircraft's designation stemmed from the *Kaira* (retribution) dual-wavelength laser/TV multipurpose sensor/guidance unit under the nose. This had an effective range up to 8km (5 miles). This made it possible to use the Kh-25MR, MP and ML, Kh-27PS and Kh-29L and T missiles.

The cockpit was fitted with an SUV weapon selector, which indicated



MiG-27.

MiG-27. (Yefim Gordon archive)

the status of each pylon and rounds of ammunition remaining, and could be set to manage the release of all dropped stores, including rocket launch modes. Another addition was the SG-1 RWR, with passive receivers in blisters on each side of the nose. These were linked to the powerful *Vyuga* (snowstorm) active jammer pod, specifically designed to protect against radar-homing missiles, which could be carried on a body pylon. The gun was the original GSh-23L.

Production of the MiG-23BK was limited, because the MiG-27K was more cost-effective. Manufacture of the MiG-23B, MiG-23BN and MiG-23BK was handled by the *Znamya Truda* factory in Moscow. The ASCC name for the MiG-23BK was 'Flogger-H'.

MiG-27M, 32-29

The main change to this tactical attack version of the *Izdeliye* 32 family was to fit the PrNK-23M navigation/attack complex, a component of which was the *Klyon*-PM (maple) laser ranger and target marker. This was not necessarily a better installation than the *Kaira*, but it was lighter and made it easier to fit side armour without disturbing the centre of gravity. The nose was simple, with the PVD probe moved down to midlevel, SP-50 ILS on the left, and the laser window in the 'chisel', with no projecting bullet on the tip. This was still intended to provide for autonomous attack by all the missiles available (listed for the MiG-23BK).

Provision was made for one body pylon to carry various reconnaissance pods (most housing three cameras as used by MiG-21s) or the control pod for a Kh-27PS (later Kh-25PM) anti-radar missile. The pilot's cockpit display had an improved screen for guiding the TV-command missile Kh-29T. Shortage of space in the cockpit forced the OKB to put the display control panel behind the seat.

The wing roots were extended forwards into narrow LERX. Each of these incorporated a *Beryoza*-L (birch) passive antenna feeding the RWR (radar warning receiver) installation, with a 100° arc of reception. The leading edge of the fin was modified to house an additional antenna for the R-864 long-range hf radio, with round-head rivets to cause turbulence. This was needed to disperse the R-864 cooling fluid, which otherwise stripped a horizontal band of paint from the right side of the fin. The rudder was fitted with dual yaw dampers.

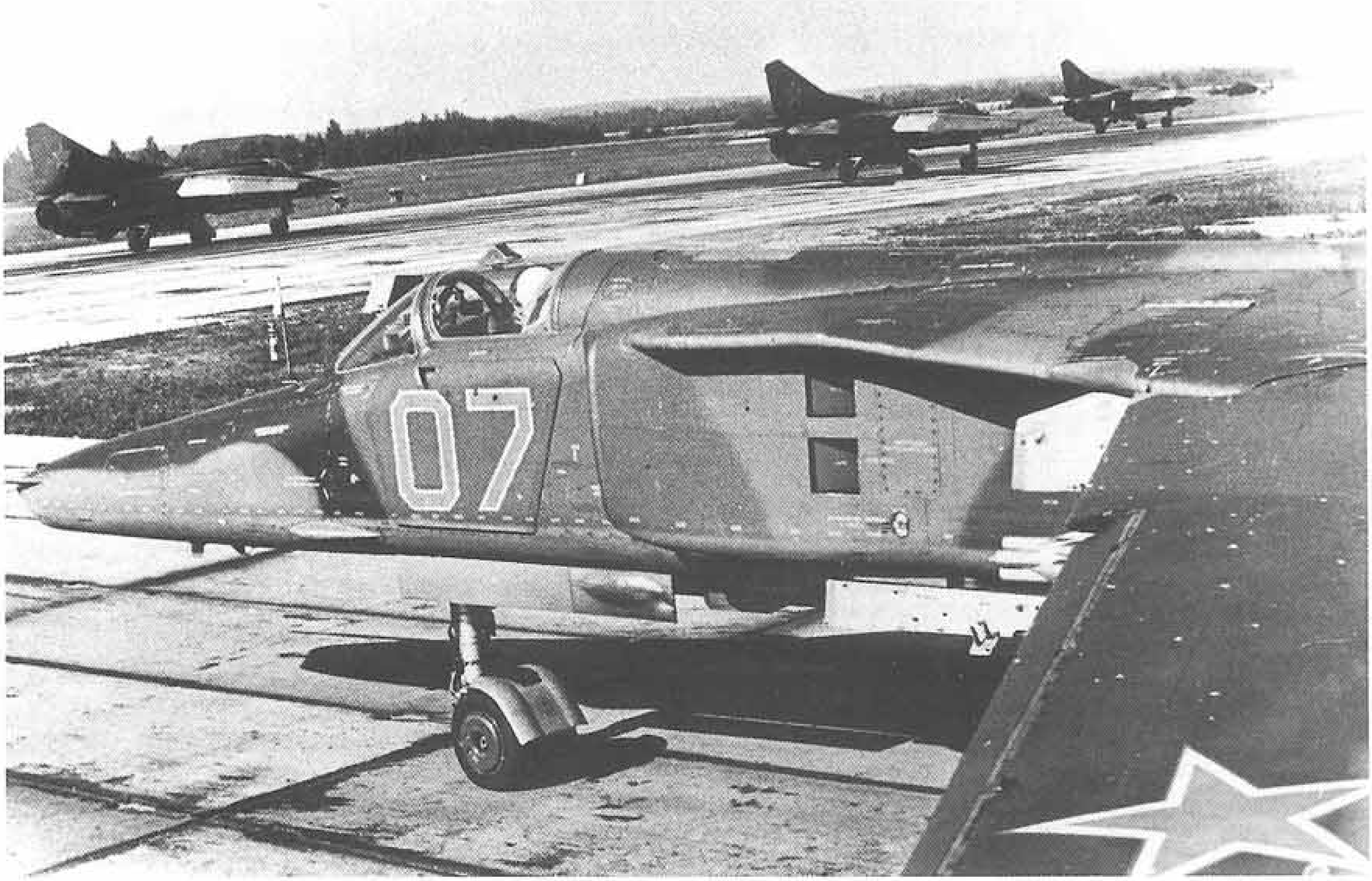
Irkutsk produced 150 MiG-27M in 1978–83, and a further number were constructed at Ulan-Ude. This brought the total of all versions of MiG-27 to 910, excluding prototypes and aircraft supplied in kit form to India (*see* MiG-27L).

Capital of the Buryat ASSR, and just across Lake Baikal from Irkutsk, Ulan-Ude had previously built helicopters. Their MiG-27Ms quickly became notorious for their poor quality. Even the Irkutsk-built aircraft were difficult to maintain, because ground personnel found the highly precise PrNK complex very demanding. It became common practice for most pilots to fly manually, guided where possible by the two or three aircraft in each regiment which were continually maintained operational in the various automatic modes. The ASCC called the MiG-27M 'Flogger-J'.

Dimensions as MiG-27.

Weight empty 11,908kg (26,252lb); internal fuel 4,560kg (10,053lb); weight loaded (clean) 16,267kg (35,862lb); maximum takeoff weight 20,670kg (45,570lb).

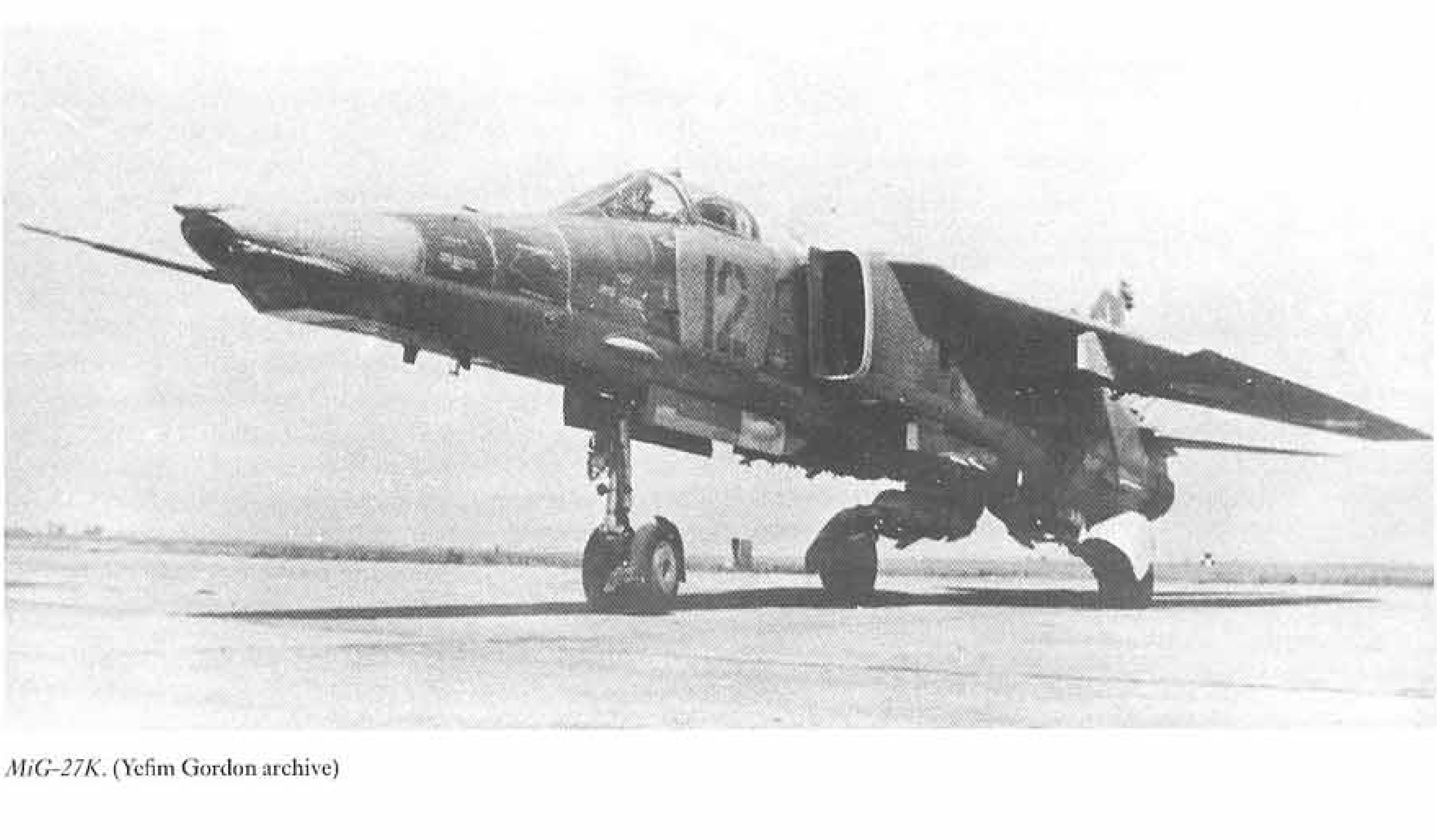
Performance very similar to MiG-27.



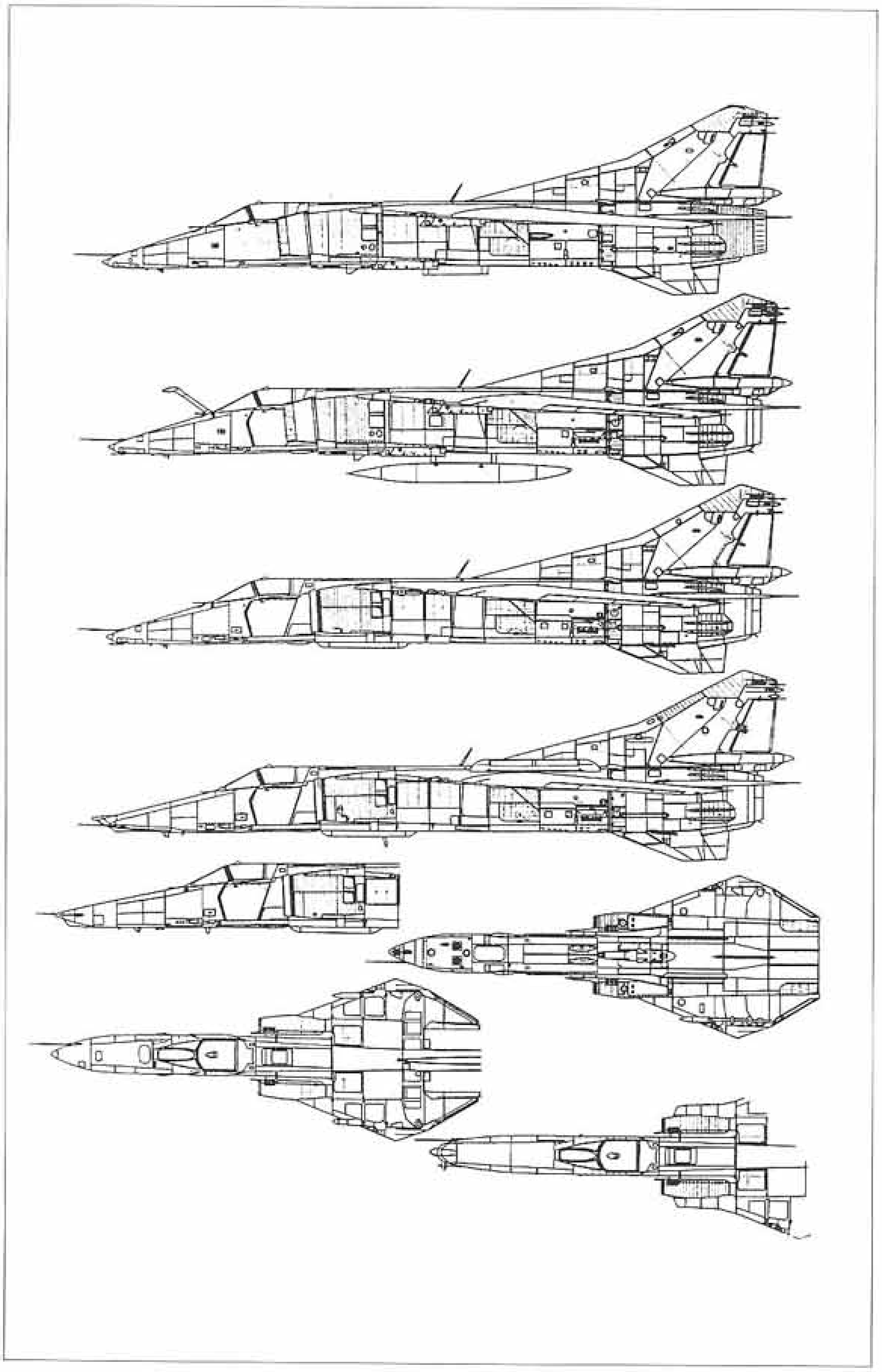
MiG-27M. (Yefim Gordon archive)

MiG-27K

This version was the most complex and advanced of all MiG-27s. It combined the PrNK-23K complex, including the *Kaira* laser, with the airframe of the MiG-27M. The distinctive nose housed the laser in a broad chin gondola with a rectangular window and the TV camera in an oval window in the chisel tip. On the tip of the nose was the projecting bullet of the *Delta*-2NG missile-guidance transmitter, which replaced those on the glove pylons. The PVD boom was moved down to midlevel, and the SP-50 ILS antenna was at the same level on the left. As the side armour slabs were removable they were often left



MiG-27K. (Yefim Gordon archive)



From the top: MiG-23B prototype; MiG-23BN (Iraq); MiG-27; MiG-27K; MiG-27M (nose); MiG-23BN (underside); MiG-27 (top); MiG-27K (top).

off, to avoid the centre of gravity being too far forwards.

The MiG-27K could carry all the missiles previously listed for the MiG-23BK. The prototype flew in 1975, and about 200 were produced at Irkutsk in 1977–82, equipping Frontal Aviation regiments 559 APIB based at Finsterwalde and 911 APIB at Brand. The ASCC name appears to have been 'Flogger-D', changed to 'Flogger-J2' after these aircraft were fitted with a LERX (leading-edge root extension). Data similar to MiG-27.

MiG-27D, 32-27

Though one of the most important of all the MiG-23/27 versions, no MiG-27D was built as such. All were constructed as MiG-27s, and in 1982–85 approximately 500 survivors were sent to the Irkutsk and Ulan-Ude factories to be brought up as nearly as possible to MiG-27M standard. The designation derived from *dorabotannyi*, upgraded. The main task was to install all elements of the PrNK-23M complex, with the *Klyon* laser, as well as the LERX with *Beryoza*-L antennas.

The MiG-27D equipped numerous Frontal Aviation regiments, including four with the 16th Air Army in the German Democratic Republic, based at Grossenhain, Rechlin, Nobitz and Mirow-Lärz. Many served in Afghanistan, where they were fitted with two KDS or ASO chaff/flare dispensers (maximum 256 cartridges) above the wing roots. Some were used as fighters with a centreline tank and a pair of R-60 missiles on each glove pylon, with GCI control into visual contact with the target. In 1993 nearly all the 360 then in front-line service were destroyed, under the terms of the CFE treaty. In 1997 'a few dozen' MiG-27s of all types remain, mainly unserviceable, in Russia, Ukraine and Byelorussia.

Externally, the MiG-27D was almost identical to the MiG-27M. Accordingly they had the same ASCC name, 'Flogger-J2'. Data similar to MiG-27M.

MiG-27L, 32-29L

This was developed by the OKB as the export MiG-27, with an airframe similar to that of the MiG-27M but with an earlier navigation/attack complex. The laser is the primitive *Fon*, and in most respects the installation is almost identical to the PrNK-23, as fitted to the MiG-27. The only missiles currently available are the Kh-23 family of attack weapons and the R-60 for self-defence. On the other hand, the gun is the GSh-6-30, and according to *Jane's* 'tactical nuclear bombs' can be carried.

The Indian government purchased a manufacturing licence in 1980 for what it has ever since referred to as the 'MiG-27M', and intended to build at least 200 at the HAL Nasik Division. The first aircraft was supplied from Ulan-Ude in October 1984, whereupon it was 'rolled out' from the Nasik plant. The first aircraft assembled from imported parts was completed on 11 January 1986, and by 1994 a total of 125 had been completed, used by the IAF with the name *Bahadur* (valiant). Since then it has been difficult to get parts from Russia. Accordingly, the planned total has been reduced to 165, and even this is proving difficult to reach. A planned midlife update is expected to replace a number of avionics items with Western equipment.

MiG-25

Studies of Mach-3 aircraft powered by two R-15B engines began at the OKB in 1958. The spur was provided by the imminent prospect of USAF Strategic Air Command deploying the Convair B-58A supersonic bomber. Other threats included the North American XB-70 Valkyrie and the Lockheed A-12 Oxcart programme, which was known in Moscow in March 1960.

According to OKB legend the programme was launched by Mikoyan himself, who in 1959 returned from the Paris airshow and encountered lead designer Ya I Seletskiy in a corridor. He suggested 'How about drawing an interceptor along the lines of the [North American] Vigilante, with two R-15B-300 engines, to fly at 3,000km/h and without complicated high-lift devices'. This was tantamount to an official go-ahead.

The OKB knew that the original scheme for the Vigilante had twin fins, which was a radical new idea for high-Mach aircraft. The sketches were shown first to head of preliminary design Belyakov, then to Matyuk and finally to Mikoyan. The proposal was of instant interest to the IA-PVO, which urgently wanted an interceptor with the range of the Tupolev Tu-128 but greater speed and altitude, and to the VVS which had lost confidence in the Tsybin RSR and urgently wanted a strategic reconnaissance aircraft. A third possibility was a strike version carrying an ALBM (air-launched ballistic missile). It appeared that all three requirements could be met by the same basic aircraft.

In February 1961 the Council of Ministers and Central Committee of the CPSU issued a joint directive ordering the OKB to develop an aircraft designated Ye-155 (by chance, the number of the OKB). It was required in two forms, the Ye-155P interceptor for the PVO and the Ye-155R reconnaissance platform for the VVS. Mikoyan signed the start-work order on 10 March 1961.

Though A M Lyul'ka was developing the AL-21 and P A Kolesov the RD17-16, the Tumanskiy R-15B-300 was always first choice as the engine. Earlier versions had powered the Ye-150 and Ye-152 testbeds, which had also provided a solid basis of knowledge on analog computers, communications, IFF and command-link receivers, air conditioning, ejection seats, flight controls and on such basic areas as aerodynamics, gas dynamics, stability and control and airframe thermal loads.

The project team soon rejected three out of four possible configurations. One had the engines superimposed, as in the English Electric Lightning. The second had a stepped layout as in the I-320. The third had underwing engines. The obvious arrangement was to have the large interception radar or the group of reconnaissance sensors in the nose, and use fully variable lateral inlets to feed the engines close side by side. With such a fast aircraft there was no point in sharp sweepback, and the decision was soon taken to put the thin wing above the engine ducts so that the spars could run from tip to tip instead of being bolted on the sides of the fuselage. Early drawings had a canard foreplane and single vertical tail. By late 1960 the canards had gone and there were two slightly sloping fins.

At this time Mikoyan asked his first deputy, Brunov, to be Ye-155 chief project engineer. For reasons not recorded, Brunov refused. Accordingly Mikoyan appointed two project heads: his old partner Gurevich was made chief of project and assigned the airframe (whilst still being responsible for missiles and RPVs), and Matyuk was assigned the integration of avionics and weapons. Sadly, Gurevich was a sick man, and could not keep pace (he retired in 1964) and Matyuk was appointed his successor.

By 1961 a large part of the OKB was working on the Ye-155. Section heads comprised: A A Chumachenko (aerodynamics), A A Sorokin and B L Kerber (aircraft systems), Ya I Seletskiy (systems integration), G Ye Lozino-Lozinskiy and V A Lavrov (powerplant and air conditioning), A V Minayev, R A Belyakov, V M Iezuitov and A A Nefyodov (flight controls and landing gear), D N Kurguzov and Z Ye Bersudskiy (structural engineering), L P Voinov (gas dynamics and thermal load calculations), L G Shengelaya (equipment), Ye V Lyubomudrov (reconnaissance sensors), D A Gringauz (chief engineer, interceptor), I V Frumkin (chief engineer, reconnaissance) and V A Shumov (chief engineer, ALBM strike).

CAHI played a major role in aerodynamics including wing design, and the LII and VNIIRA jointly developed the *Polyot* navigation system. This comprised an on-board autopilot, computer, flight-parameter measurement system, combined navigation/ IFF set and an antenna/feeder set. The ground portion comprised *Svod* (arch) and *Doroga* (road) RΘ beacons and the *Katet* (side of a triangle) localizer/glideslope beacon. The interceptor was to be compatible with the *Vozdukh*-1 (air) ground-to-air guidance system. Both the interceptor and reconnaissance versions were to be capable of largely automated navigation in all weathers, finally making an automatic landing.

Before detailed descriptions of the aircraft that were actually built, it is appropriate briefly to mention some of the early projects that remained on the drawing board. The first two are illustrated overleaf.

Ye-155R project

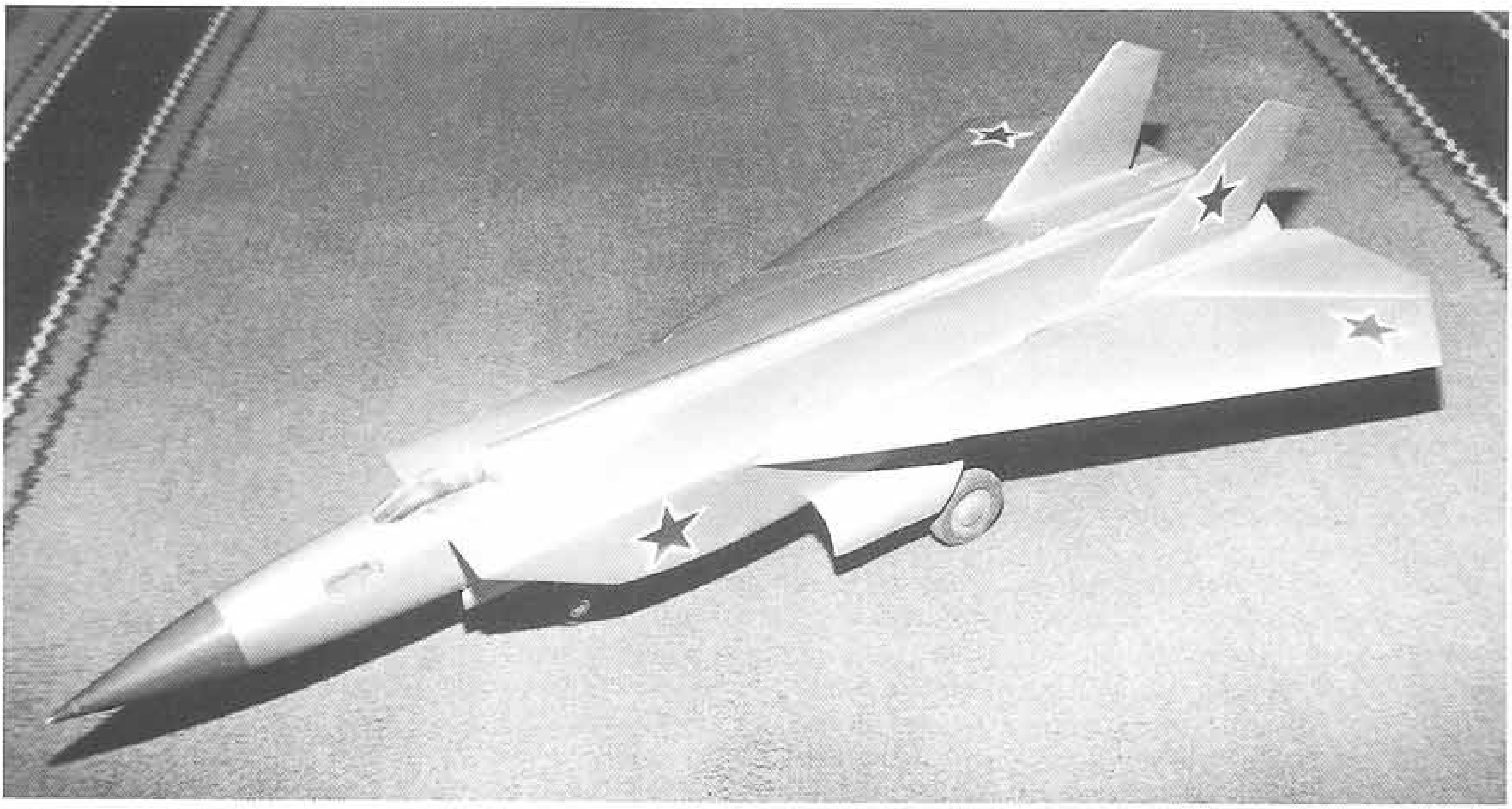
This was to be a high-altitude reconnaissance aircraft. It would have had a variable-sweep wing similar to that of the General Dynamics FB-111A, and a pressure cabin extended forwards from the pilot's cockpit to house a navigator station. Both features were considered unnecessary.

Ye-155R (VD) project

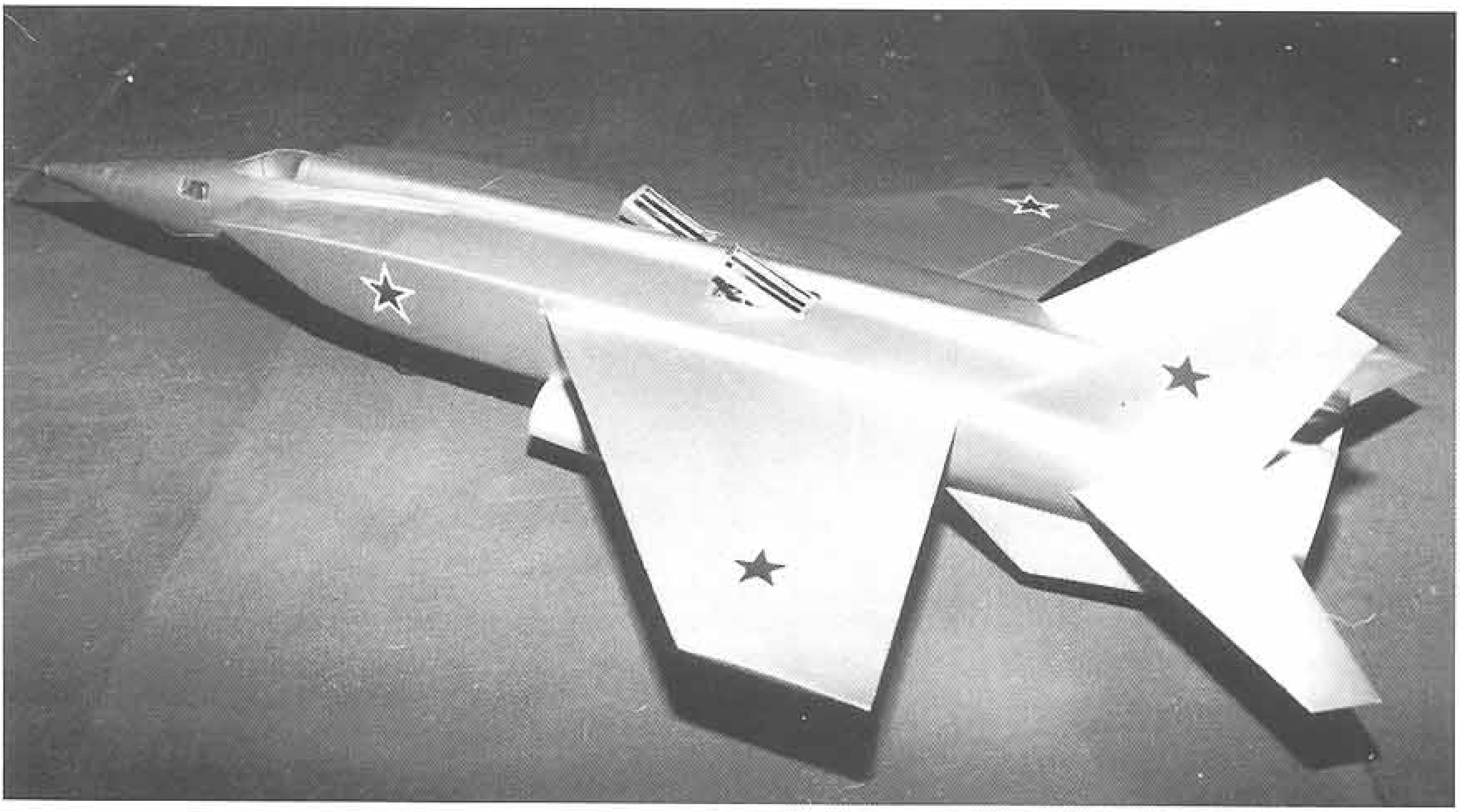
Two models were built of this alternative STOL version with RD36-35 lift-jets in the centre fuselage. One had a pointed nose housing reconnaissance sensors, and two pairs of lift-jets, one on the right ahead of the centre of gravity and the other on the left the same distance behind. The other project had a capacious nose housing radar and a total of eight lift-engines, each group of four being covered by an upwards-hinged grill door incorporating a section of the spine. Both would have had the forward navigator station.

Ye-155N project

With a designation from *nositel* (carrier), this was projected in 1961 as the proposed launch platform for a strategic missile. The OKB was to collaborate with the Moscow Thermal Equipment Institute on an ALBM and with the *Raduga* design bureau on a cruise missile. Eventually



Ye-155R variable-sweep project model. (photograph by Yefim Gordon)



Ye-155R (VD) project model. (photograph by Yefim Gordon)

this promising project was put on hold, though in the late 1970s there were two attempts to revive it.

Ye-155RD project

This 1961 study was an attempt to fly reconnaissance missions at low and medium altitudes. The basic aircraft resembled the Ye-155N but instead of a missile it carried an RPV. This could be expendable, or it could fly back at low level to a preprogrammed recovery zone, and would carry day or night cameras, low-light TV or side-looking radar, plus a data link to send all the information in real time to the 'mother ship'. The latter would remain at high altitude and would itself carry various suites of cameras and Elint receivers and recorders.

Ye-155Sh project

With a designation from *shturmovik* (armoured attacker), it was soon decided that the Ye-155 was totally unsuited to low-level attack.

Ye-155ShR project

This proposed dual-role low-level attack and reconnaissance aircraft was likewise judged to pose too many challenges (to structure, navigation and the pilot, for example).

Ye-155 bizjet project

Studied in 1963–65, this would have had a wing of increased span and a new forward fuselage equipped with up to seven passenger seats or up to 1,000kg (2,205lb) of urgent cargo. The entrance door was on the left behind the cockpit. The fuselage was slightly wider, increasing fuel capacity to give a range up to 3,500km (2,175 miles) at Mach 2.35. The VVS showed some interest, but the work was mainly funded by the OKB, which decided that the probable market did not justify the large design effort.

Ye-155 engineering design

In February 1962 the OKB received a directive ordering the construction of several prototypes. A vast amount of paperwork was issued to manage the enormous amount of research and development needed. The initial specific operational requirement was for the Ye-155R reconnaissance version, for which the equipment suite was finalized in September 1962. The corresponding document for the interceptor was signed on 15 June 1963, as described later.

Though the basic configuration had been agreed in 1961, by 1962 urgent studies were still proceeding to determine such basic decisions as the materials to be used. By this time Mikoyan had appointed Belyakov to replace Gurevich as his first deputy general designer. Under him were the team listed earlier, headed by project director Matyuk, plus P Ye Syrovoi (technical documents) and V A Arkhipov (lead engineer for the first prototype, the Ye-155R-1). Minayev was assisted by famed polar flyer A V Lyapidevskiy in creating the unprecedented test rigs and testbeds.

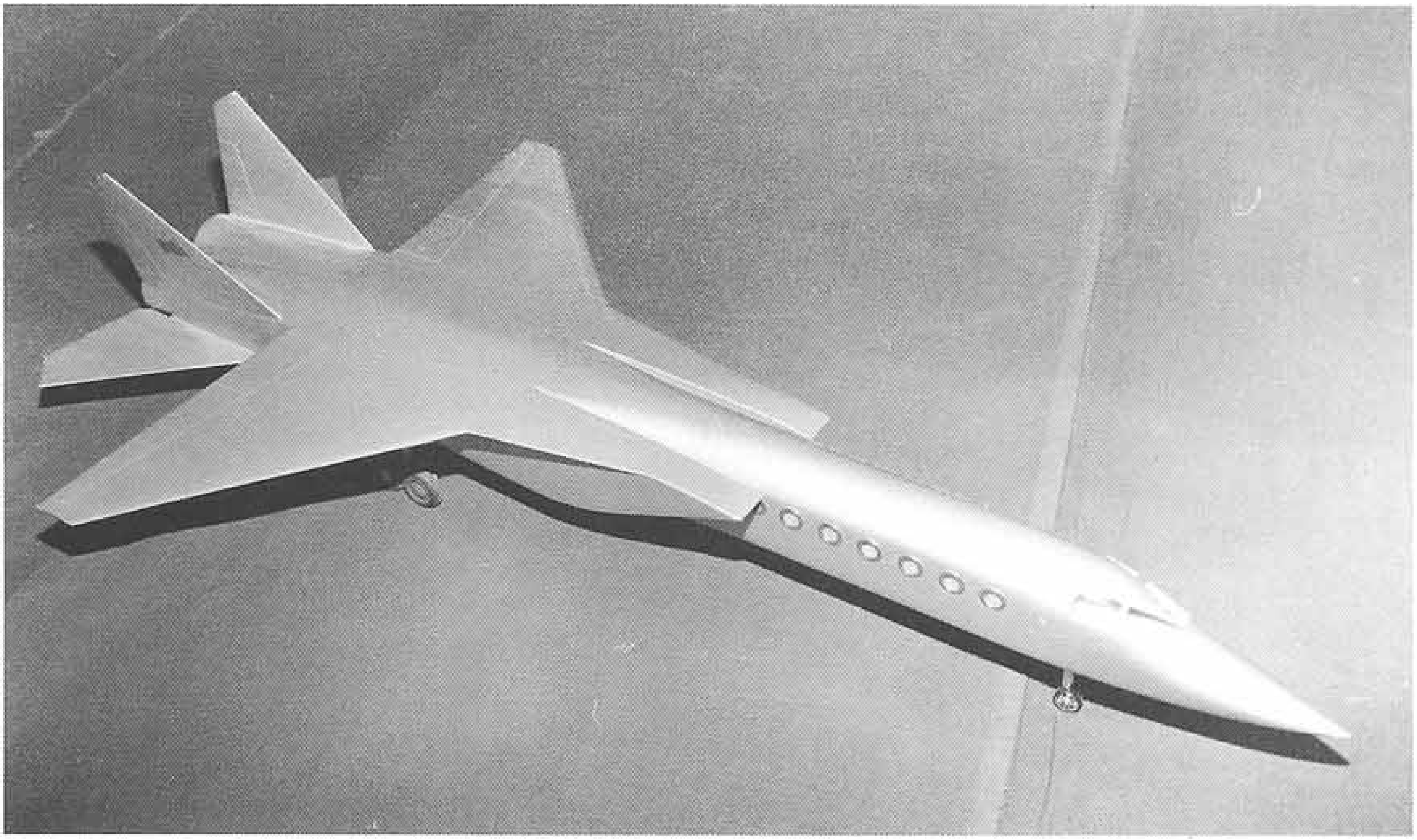
Flying testbeds included the Ye-150, Ye-152 and Ye-152M for the engine, plus a Tupolev Tu-16LL with an R-15B-300 extended from the weapon bay. For the avionics (described later) two Tu-104Bs were equipped to test the *Peleng* navigation suite, with several versions of the first Soviet airborne digital computer, the *Anis* INS, the *Strela* doppler and the *Tropic* radio navaid. The reconnaissance equipment and their producers are described later.

Many other organizations were involved. Apart from CAHI for aerodynamics, there were the Ramenskoye Instrument KB, GosNIIAS (State Aircraft Systems Research Institute), the Moscow Instruments Research Institute, *Soyuz* engine KB, *Voskhod* engine KB, *Mars* engine KB, *Pal'ma* Scientific and Production Association, the All-Union Technology Research Institute, the State Radio Communications Research Institute, *Avionika* Scientific and Production Association, Kursk Industrial Automation KB, *Ekran* plant in Kuibyshev (now Samara), *Detal* KB in Kamensk-Ural'skiy, optical and mechanical equipment groups in Kazan and Krasnogorsk, the Central Aero-Engine Institute (CIAM), the All-Union Aviation Materials Institute (VIAM) and many metallurgical institutes and specialized laboratories. Former Factory No. 21 in Gor'kiy had a massive task in getting ready to produce the eventual series aircraft.

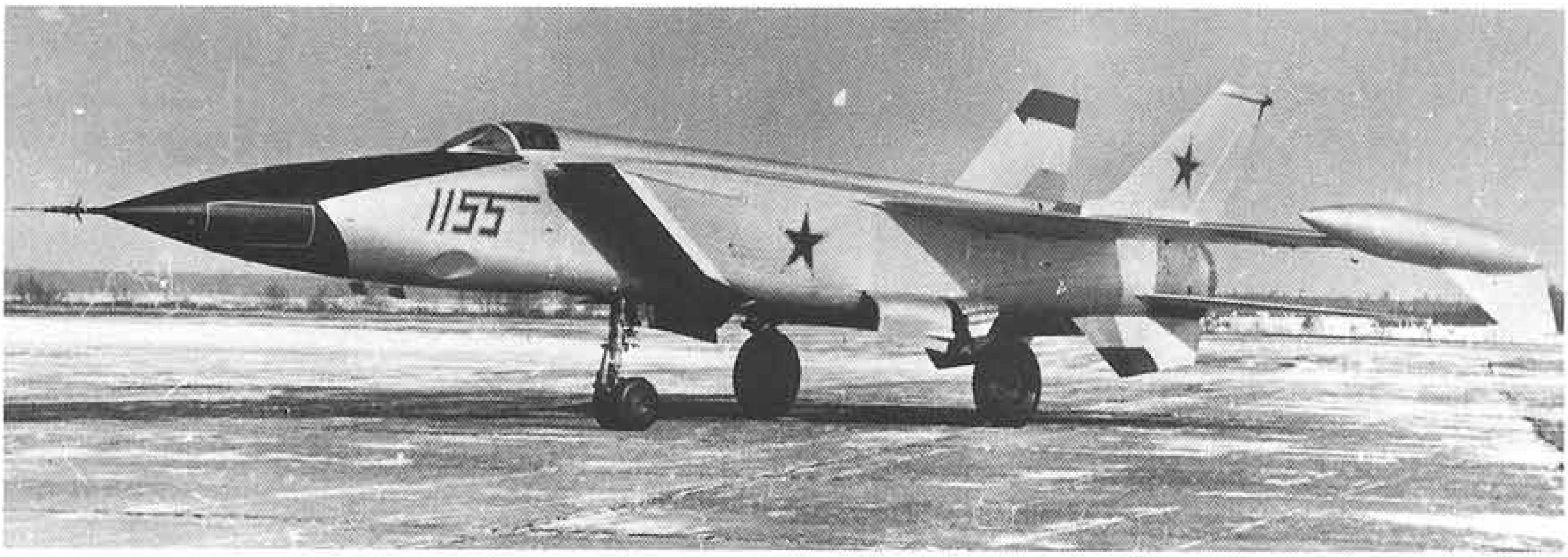
Ye-155R-1 and R-2 prototypes

The Ye-155R-1 was the first of what eventually was to grow to be the most prolific family ever to come from the Mikoyan OKB. It is appropriate to describe it in detail, thereafter outlining the differences characterizing other versions.

The high-mounted wing was constructed in one piece, with three spars. The main structure was made from VNS-2, VNS-4 and VNS-5 high-strength heat-resistant stainless steels, assembled mainly by the automated welding methods devised by Ye O Paton and used for large missiles.



MiG-25 passenger project model. (photograph by Yefim Gordon)



Ye-155R-1. (OKB)

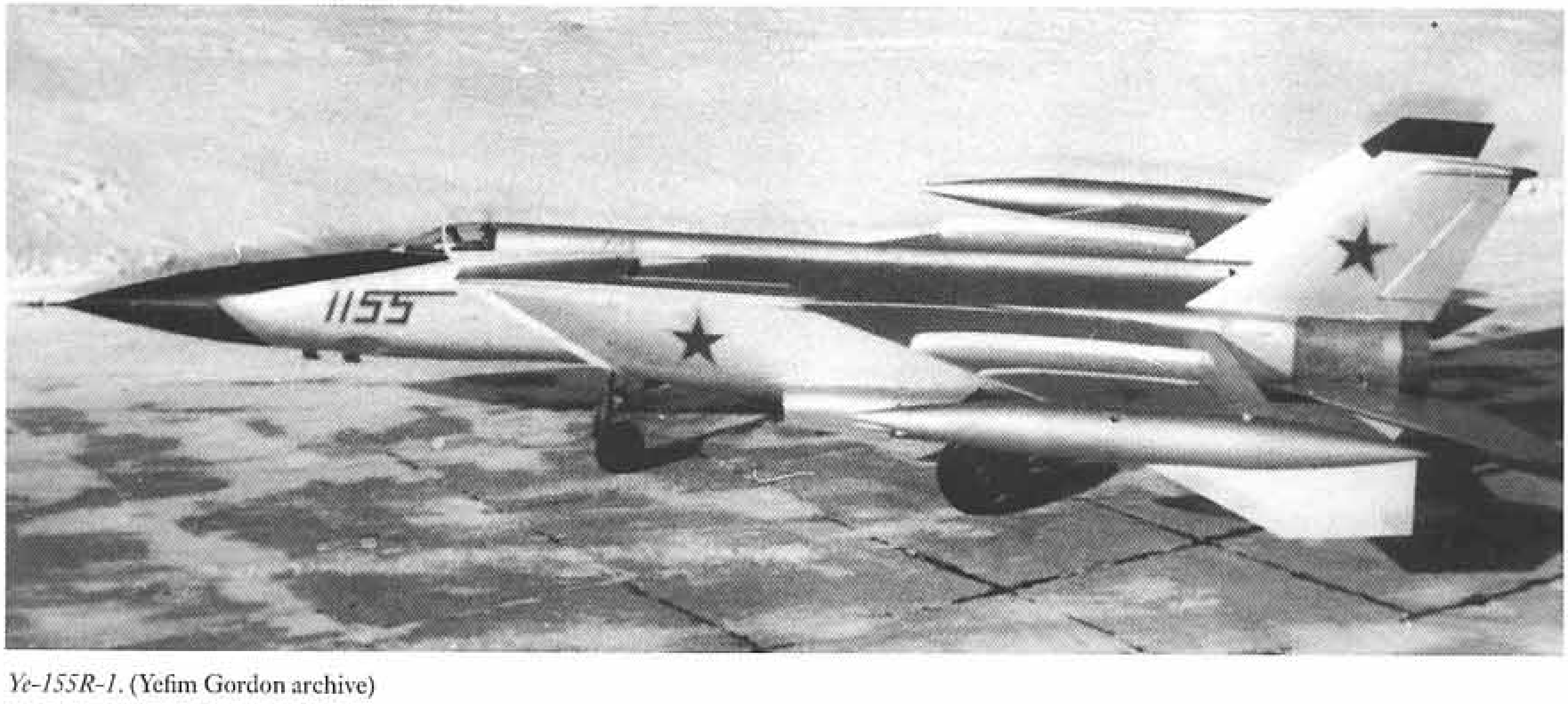
Aerofoil profile was CAHI P-44M at the root with a thickness/chord ratio of 3.7 per cent, changing to P-101M at the tip, where thickness/chord ratio was 4.76 per cent. Leading-edge sweep was 41°02′, dihedral zero and incidence zero. Aspect ratio was 2.94.

The fixed but detachable leading edge was made of OT4-1 titanium alloy, and housed cables and fuel pipes. The trailing edge was again OT4-1 and at the root incorporated attachments for the bellcranks to drive the flap and aileron. The rear end of Rib 22 carried the attachments for the outer end of the flap and inboard end of the aileron. Each flap was a simple surface with skins riveted on a honeycomb core, pivoted on two hinges and driven with flap blowing to 47° for landing. The ailerons were of similar construction, in two interlinked parts driven to ±25° by a power unit at the midpoint served by pipes run externally above and below the wing tanks. A D19T fence extended from the leading edge across the upper surface to near the outer end of the flap, and a shallow fence extended from the leading edge to the joint between the inboard and outboard ailerons. Very large tip tanks carried outwards-sloping ventral fins (inverted winglets). These made up for the zero incidence of the wings by increasing longitudinal stability while decreasing lateral stability. It was also thought that they enhanced basic wing efficiency.

The fuselage, much bigger than that of any previous MiG, was made in one piece, with no removable rear section. Length was 19.581m (64ft 2⅞in) and cross-section area 5.54sq m (59.63sq ft). It was made of VNS-2, VNS-5, VL-1, EI-703, EI-878 and SN-3 steel, D19T heat-resistant aluminium alloy and OT4-1 titanium. Again, almost all the joints were made by contact and arc welding.

The nose up to Frame 2 was a semi-monocoque with D19T skins which were mainly riveted. Reconnaissance sensors (absent on the first prototype) were mounted on a pallet which was raised on cables by a winch and then latched to form part of the load-bearing structure. The large access hatch was then secured by special bolts.

The pressurized cockpit was located between Frames 1 and 2. The flat windscreen was 20mm thick and the canopy 12mm thick, the material being special E-2 heat-resistant Plexiglas. The canopy hinged to starboard manually by means of an external handle and an internal folding strut. All glazing had ethyl-alcohol de-icing, actuated by a button. Usually 2–3 seconds of operation was sufficient. The



Ye-155R-1. (Yefim Gordon archive)

KM-1 seat ran on guide rails attached to the floor at Frame 2, which also contained a cutout for the nosewheels.

The oval-section semimonocoque structure continued behind Frame 2, the nosewheel bay being in the centre with avionics racking above and on each side. Structure was mainly D19T, with skin spot-welded to Frames 2a and 2b, web frames 2v, 2g and 2d (the next characters in the Cyrillic alphabet) and longerons and stringers. The avionics bay was separated from the nosewheel bay by a pressure bulkhead riveted to a hollow beam assembled from angle-sections. This beam contained flight controls, accessed via the removable top, as well as the nosewheel actuator between Frames 2v and 2g and the downlock, the leg itself being pivoted to Frame 3. The avionics bay was pressurized and thermally insulated by ATAZ mats faced with ANT-7 fabric bonded to the walls. The large access panels were edged with rubber seals and secured by quick-release fasteners.

The central fuselage formed a very large integral tank extending from Frame 3 to Frame 12. It was welded from VNS-2, -4, -5 and SN-3, with the bottom and some internal webs of D19T. Joints were mainly argon-arc and spot welding. This tank formed the main load-bearing part of the fuselage, joining all other parts of the aircraft.

The tank itself is described later with the fuel system. The centre fuselage had ten main frames, Frame 8 carrying the main landing gear with the downlock struts attached to Frame 9, and the wheel bays each having two doors on Frames 6–9. The lower fuselage between Frames 9 and 13 incorporated very large hinged or removable panels for engine maintenance. To change an engine the afterburner was disconnected and removed to the rear and the main part of the engine was then lowered onto its trolley.

The aft fuselage (Frames 12–14) was made almost totally from VL-1 steel. Frames 13 and 14 carried the six components of the tail unit, and Frame 14 additionally carried the upper and lower airbrakes. The upper airbrakes comprised two panels of 1.3sq m (14sq ft) total area, each hinged at the front and driven by an actuator at its inner end to a maximum of 45°. The lower airbrake was a single wide rectangle of 1sq m (10.76sq ft), driven by two actuators to 43°30′.

Called the tailcone, the rearmost section of fuselage comprised an internal structure of spot-welded steel to which was riveted the external webs and skin of spot-welded titanium. It incorporated the recesses for the airbrakes, the upper section including the final section of the dorsal spine which formed the duralumin container for the braking parachute. This section was riveted to Frame 14.

The twin fins each had three spars and were made of VNS-5 and AK-4 duralumin, with skins of D19AT. Each had a leading-edge sweep of 54°, with an outward cant of 8°. Each had a root chord of 3.31m (10ft 10⅜in) and a height above the root of 2.47m (8ft 1⅛in) to a flat horizontal top, the leading edges and tops of the fins incorporating different antennas and equipment. Each fin was attached to Frames 11a, 12, 13 and 14, and carried a rudder mounted on three hinges driven by a lever at the bottom. Total vertical tail area was 12.8sq m (137.8sq ft), of which the rudders contributed 2.12sq m (22.8sq ft).

The slab tailplanes had a span of 8.74m (28ft 8in), leading-edge sweep of 50°22′ and total area of 9.81sq m (105.5sq ft). They were carried on spigots at 50 per cent chord mounted on longitudinal beams near Frame 14. In the production aircraft the trailing edges were curved up 2° and the limits of movement varied from –32°/+13° at takeoff and landing to only –12°30′/+5° in supersonic cruise. Under the rear fuselage, as wide apart as possible, were the two large ventral fins (keels). Each was 3.6m (11ft 9¾in) long and their total area was 6sq m (64.6sq ft), the forward part of each keel being an antenna.

The engines were Tumanskiy R-15B-300 turbojets each rated at 7,500kg (16,535lb) maximum dry and 10,210kg (22,509lb) in afterburner. They were installed through the removable underside of the fuselage downstream of Frame 9 and attached to Frames 10 and 11. Each was rotated 13° so that the accessory gearboxes on the underside faced away from each other and were thus more accessible. For aerodynamic reasons the nozzles were tilted 2°30′ up and 1°46′ inwards, and to reduce frontal area the jetpipes were brought so close together that the nozzles overlapped. To allow this, the three inboard segments of each three-position nozzle were removed and replaced by a central fairing. Each engine bay was lined with steel with a 30μ-thick coating of silver (5kg, 11lb, of silver per aircraft) backed by glassfibre wool blankets and cooled by boundary-layer air.

Each engine was supplied with air from one of the largest inlets ever flown. In front view the inlet was almost square, with sharp edges, standing well away from the fuselage, the sides being swept at 60°. Inside the duct the upper wall comprised front and rear sections mounted on hinges and hydraulically driven to vary throat cross-section and wall angle. Other actuators controlled large discharge panels in the top of the duct. The front panel was perforated to suck out boundary layer, and the aft segment carried vortex generators to energize the airflow. To minimize losses the lower lip of the intake was hinged and could be set to any of three angles according to indicated airspeed (IAS) and AOA. Though each duct was almost straight, its outer wall curved in to leave room for the bay for the main landing gear. The engines and inlets were automatically controlled by an RRD-15B electronic system, sensitive to IAS, AOA and the position of the pilot's throttles. Each engine was started electrically, either by batteries or by ground power. Each engine had its own fire-protection system, with ionization sensors and bottles holding 6.75kg (14.88lb) of $114V_2$ CFC (chlorofluorocarbon).

As in the Ye-152P, the Ye-155R-1 had provision for large canards to be attached at the front of each engine inlet, to enhance pitch control at high Mach numbers. The attachment spigot would have been bolted on at the location of a small removable panel, the movable surface butting against a shallow fixed root section which can be seen in photographs. These canard surfaces were never installed, because it was found that the upper surface of the inlets had the same effect.

All three units of the landing gear retracted forwards. The main units had single Hydromash shock struts inclined back and slightly out when extended to give a track of 3.85m (12ft 7½in). The wheels were KT-111A, with multidisc brakes and 1,300 × 360mm tyres. The nose leg was raked forwards to give a wheelbase of 5.144m (16ft 10½in). It had twin KT-112A wheels, fitted like the main units with antilock brakes, with 700 × 200mm tyres. The nosewheels were steerable, with different turn limits for low-speed and high-speed taxiing. The doors remained open when the landing gear was extended.

All versions of MiG-25 had two braking parachutes. Prototypes and early series aircraft had circular canopies each of 30sq m (323sq ft) area, while in most production aircraft the canopies were of cruciform shape each with an area of 25sq m (269sq ft). The parachutes were streamed automatically on landing by a sensor in the left ventral fin.

The fuel system posed severe challenges. Initially only T-6 kerosene was specified, with T-7P as a substitute, but later RT jet fuel was found acceptable. The fuselage was divided by bulkheads into Tank 1 (2,810 litres, 624.4gal), Tank 2 (3,220 litres, 715.5gal), Tank 3 (3,060 litres, 680gal), Tank 4 (2,340 litres, 520gal), Tank 5 (2,370 litres, 526.6gal) and Tank 6 (730 litres, 162.2gal).

Except for the extreme leading and trailing edges the wing was also welded into four integral tanks. Those ahead of the front spar had a capacity of 550 litres (122.2gal) each, and those inside the main structural box housed 1,910 litres (424.4gal) each. On the tips were fixed circular-section tanks each with a capacity of 600 litres (132gal). Each fin was also sealed to form an integral tank with a capacity of 350 litres (77gal). Thus, total capacity was 18,890 litres (4,155gal), all of it protected by nitrogen supplied to replace fuel as it was consumed.

All flight-control surfaces were fully powered by irreversible tandem-cylinder power units. Each tailplane was driven by a BU-170, and each aileron by a BU-170E (E for *eleron*). These were all signalled by push/pull rods. A single BU-190 was mechanically linked to drive both rudders. This was signalled by double cables inside the dorsal spine. An ARU-90A artificial feel system progressively reduced tailplane movement according to q (dynamic pressure), whilst simultaneously providing q-feel on the stick. An MP-100M automatic trimming mechanism eliminated stick and pedal loads in cruise without the need for tabs on the surfaces. The SAU-155 autopilot is mentioned later.

Each engine drove two NP-70A hydraulic pumps, one in the General hydraulic system and the other in the Booster system. The fluid was 7-50S-3 silicon-based, and the cutout pressure 210kg/sq cm (3,000lb/sq in). The General system powered one cylinder in each flight-control power unit, as well as the landing-gear, flaps, airbrakes, wheel brakes (separate subsystems for normal, emergency, mainwheel autobrake on retraction and aircraft on tow with engines off), nosewheel steering, inlet ramp (normal and emergency), inlet upper door and lower intake lip. In series aircraft it closed the APU inlet after main-engine start. The Booster system powered the other cylinder in each surface power unit and standby emergency wheel brakes. The duplicate pump drives ensured that, for example, the inlet ramp of a failed engine remained operative, to enable a relight to be achieved.

Each engine drove a GSR-12KIS generator producing direct current feeding separate circuits and also charging a 15SCS-45B Ag/Zn (silver/zinc) battery. Each engine also drove an SGK-11/1.5KIS alternator via a PPO-20 constant-speed drive to generate single-phase current at 200/215V at 400Hz. A T1.5/02 transformer produced 400Hz at 36V, and in emergency a PTO-100/1900 rotary converter could supply at 120V.

Bottle storage provided air for the pneumatic systems. A total of 14 litres served the Main system, which pressurized all seals, controlled the wheel brakes, canopy de-icing, fuel jettison, generator cooling vents, automatic and manual brake-parachute deployment and manual parachute release, nitrogen fuel-tank inerting and, in later versions, APU inlet opening and the winch for special mission pallets. Ten-litre bottles supplied the Emergency system, for emergency landing-gear extension and adjusting the inlet ramps before landing. A 2lit bottle served a third system which pressurized the avionics bays and the cooling tank for (on reconnaissance versions) the Sigint and (on interceptors) the main radar.

Engine bleed supplied the environmental systems for the cockpit and avionics bays. The former required air at the rate of 240kg (529lb)/h, and the avionics at 560kg (1,234lb)/h. The hot high-pressure air was passed through primary air/air-heat exchangers and a water radiator. Inside each subsystem the air was further cooled, that for the cockpit being supplied at –7°C and 0.45kg/sq cm (6.4lb/sq in) and for the avionics being cooled to –20°C at 0.075kg/sq cm (1.07lb/sq in). Cockpit temperature was normally held at 20° (68°F).

The life-support system included a KKO-5LP gaseous-oxygen system. If the pilot ejected, his supply switched automatically to the KP-27M bottle, sufficient to last during the descent from extreme altitudes. Pilot clothing included a VKK-6M pressure suit or VK-3 ventilated suit and a GSh-6 pressure helmet. For lower altitudes the ZSh-5 or -7 lightweight helmet was adequate. For overwater missions a VMSK-4 or -2M marine high-altitude suit was worn, with ASP-74 lifebelt or ASZh-58 lifejacket and gloves. A *Komplekt*-L suit was available for NBC environments. The KM-1 seat included all the expected survival gear, including a *Komar* (mosquito) radio beacon and a dinghy.

Like other MiG prototypes, the Ye-155R-1 was built in the OKB shop, which by the 1960s was given the cover name of Zenit Machinery Works. It was prepared by V A Arkhipov, assisted by L G Shengelaya, monitored by G A Sedov and K K Vasil'chenko, head of OKB flight test. The aircraft was painted grey, with a black nose and callsign 'Red 1155'. After data recorders and a telemetry antenna under the nose were installed it was flown by Fedotov on 6 March 1964. He was soon joined by Ostapenko.

This outstandingly exciting and challenging aircraft proved a delight to fly, until it penetrated the transonic region. Then, as in some earlier MiG prototypes, the aircraft tried to roll, even resisting full opposite aileron. Pilots tried accelerating through the speed of sound with opposite bank applied. At Mach numbers beyond 2 static stability deteriorated alarmingly. Shockwaves and turbulence in the inlets gave rise to a visible mist of condensation, and the afterburners tended to flame out at high altitude, both of which caused serious buffet and vibration. At all speeds further jerking vibration was caused by fuel sloshing in the tip tanks as the fuel level in these tanks fell. Another problem was that fuel burn was above prediction, especially in the climb, and takeoff weights were heavier than expected.

Later in 1964 the first interceptor prototype (Ye-155P-1, described later) began its flight-test programme, backed up by the various testbed aircraft described earlier. In early 1965 the Ye-155R-2 entered flight test, differing mainly in omission of the troublesome tip tanks. During 1965 Fedotov and Ostapenko were joined by test pilots from the LII and NII-VVS and the Gor'kiy factory. The OKB programme was completed in about 200 flights, at the end of which stability and controllability were acceptable and specified performance fully met. Tests at Mach 3 quickly scorched and blackened the painted airframe, until a special high-reflectivity heat-resistant grey finish was developed.

As the reconnaissance (R) and interceptor (P) versions differed considerably, and were considered equally important, separate teams were organized to test both in parallel.

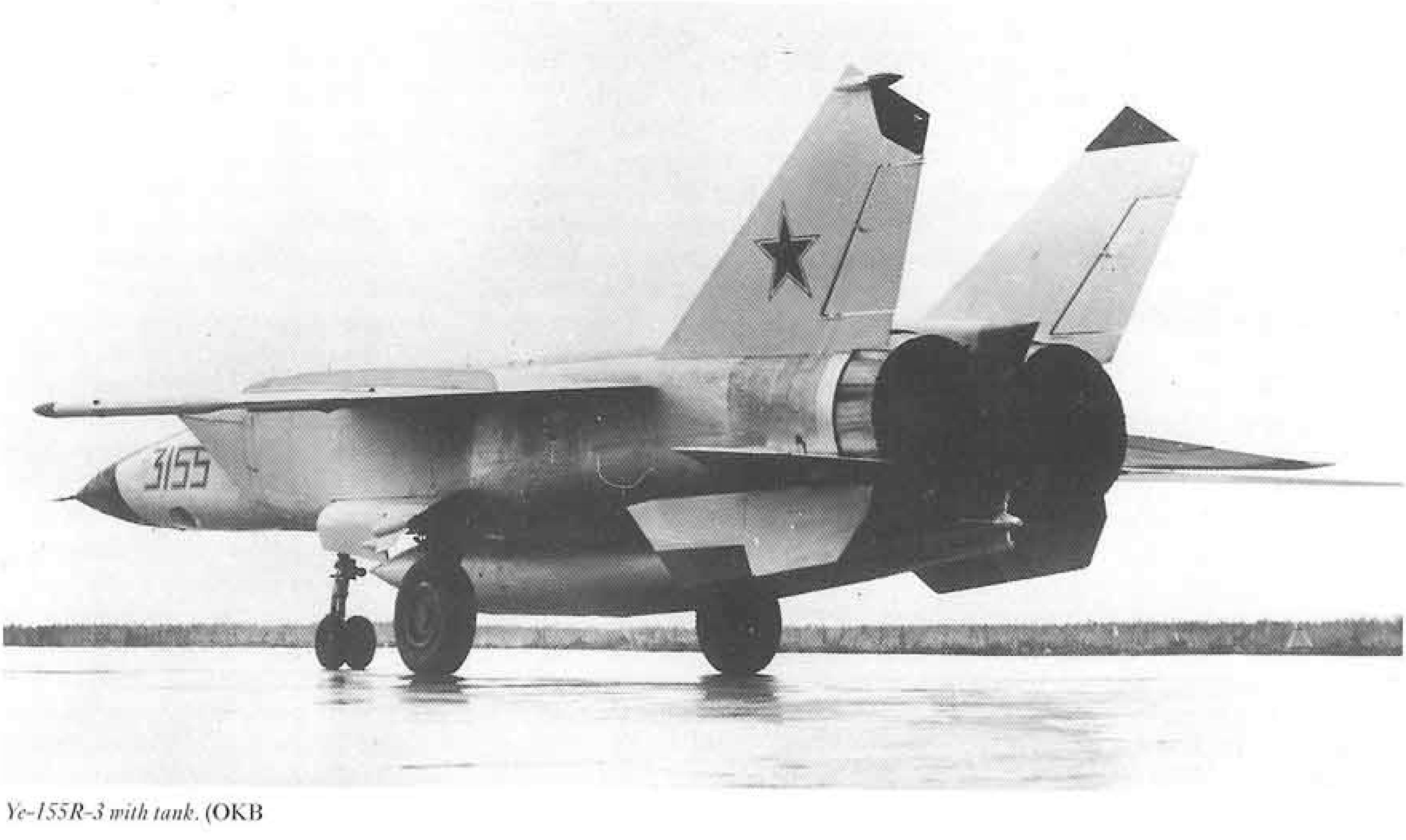
Because of the unprecedented complexity of these aircraft, and the degree of urgency, it was obvious that a substantial number of prototypes would be needed to complete development. The OKB's Zenit factory was small, and already committed to manufacturing the 23-01 and 23-11, so in 1963 it was decided to tool up the huge Gor'kiy factory to produce preproduction batches of both Ye-155 versions. Though a formidable task, in the longer term this was expected to speed the transition to full production.

Accordingly, preproduction aircraft emerged from Gor'kiy before the end of 1965. The first to appear was the Ye-155R-3, callsign 'Red 3155'. This was the first to carry a complete avionics and camera fit, for testing day photographic installations. The wings were redesigned with reduced span and area, and constant leading-edge sweep of 41°02′. They were set at +2° incidence, and the wingtip tanks were replaced by slender antiflutter masses called 'balance booms'. The fins were unchanged in height but a triangle was cut from the top at the Mach angle of 60°; this required rearrangement of the antenna covers. Structural changes were made in the forward fuselage to house the cameras and associated systems. Not least, the fuselage was equipped to carry underneath an external fuel tank of exceptional size, the capacity being 5,300 litres (1,166gal).

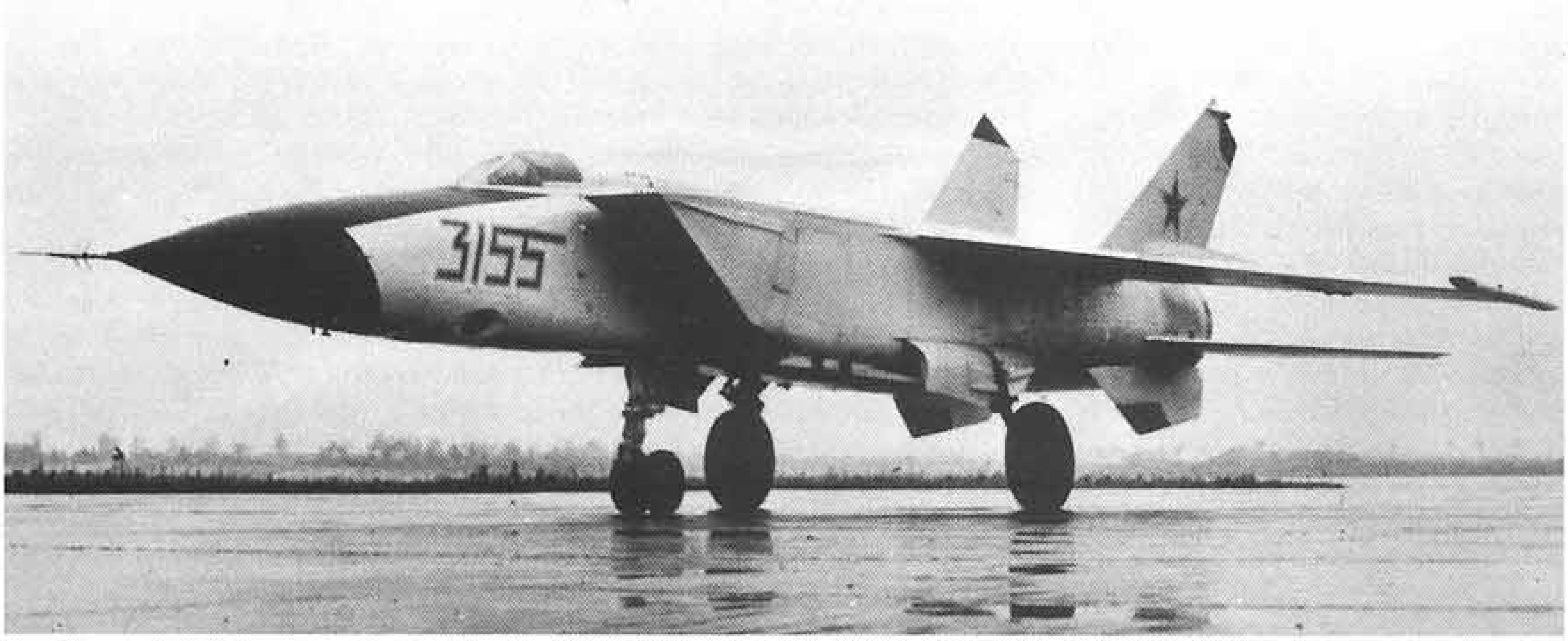
Almost all the testing for the MiG-25R was done with this aircraft. It was flown for the OKB by A V Fedotov, P M Ostapenko, B A Orlov, O Gudkov, A V Kravtsov, I Lesnikov and others. At the new NII-VVS test centre at Akhtubinsk the test team under Col Rumyantsev included project chief test pilot Col A S Bezhevets and military engineers B Klimov, V Tokarev and A Klyagin. It took over two years and several hundred flights to find answers to such questions as the way shockwaves, the boundary layer and vibrations affected picture quality, whether having the outer lenses at 250°C would cause distortion, or whether repeated heating and cooling would affect the cameras or make the port glazing brittle.

With the much slower Yak-27R picture resolution in flight degraded to 10 lines/mm, only one-third as good as on the ground. With the Ye-155R-3's very large A-72 and A-70M cameras focal length ranged from 750 to 1,200mm (29.5–47.24in), and to improve resolution they incorporated Invar in their construction and were housed in compartments maintained at 35–50°C. Their nose location meant the boundary layer was thin. Finally, the resolution achieved at Mach 2.35 at 20km (65,616ft) was 30 lines/mm. In practical terms this meant a resolution of 30cm (11¾in) for the A-72 and 40cm (15¾in) for the A-70M. Results were also acceptable at lower altitudes and speeds.

The Ye-155R-3 also tested the A/E-10 topographic camera designed by the *Peleng* KB in Minsk, and later the SRS-4A and SRS-4B Sigint (signals intelligence) installations without major problems. The SRS-4A was designed to detect centimetric and decimetric-waveband radars. After detection each signal would be amplified, classed by frequency, converted



Ye-155R-3 with tank. (OKB



Ye-155R-3. (OKB)

and recorded by a photographic registration unit. The SRS-4B fitted in the same avionics racking and differed only in the range of frequencies. In each case the large antenna was behind an approximately square dielectric window in each side of the nose.

The second preproduction aircraft, Ye-155R-4, represented the final series standard. Thus, it was used for performance testing and reconnaissance-suite calibration, A Ya Ischenko being engineer in charge. New items which it tested included the complete navigation systems, several interchangeable liquid-cooled ECM pallets and the R-847 *Prizma* (prism) hf radio for global communications. This work was assisted by G N Burov, assigned from the Ramenskoye instrument KB.

Of the two navigation systems, the *Peleng*-S (bearing-S) posed few problems, though many flights were necessary to check each operating mode, obtain statistical data and make adjustments (for example, to the autopilot gear ratios). It was a different story with the second system, *Polyot*-1I (flight). This comprised a triple inertial system, *Strela* (arrow) doppler for ground-speed/drift measurement and the *Orbita* (orbit) digital computer. Despite the computer's frequent failures, the strong test team, joined by R A Sheklov-sipyants of the Elektroavtomatika KB, managed to persuade the VVS that reliability would improve under service conditions, and were proved correct. Accordingly, A A Pol'skiy, chief of the avionics test department, cleared the Ye-155R for production whilst relying temporarily on the *Peleng*-S suite.

The State Commission held to this view even when the Ye-155R-5 crashed on its acceptance flight at Gor'kiy on 30 August 1965, injuring test pilot L I Minenko. Last of the preproduction aircraft, Ye-155R-6, was stationed at the Mikoyan OKB facility at LII-MAP Zhukovskiy. A seventh airframe was used for static testing. Finally, in late 1969 the State Commission under the chief of reconnaissance, Maj-Gen Seelin, signed the Act of Acceptance for the MiG-25R, described later.

Ye-155P

The first interceptor prototype, and the second of the Ye-155 prototypes to be completed, the Ye-155P-1 left the OKB Zenit factory in early August 1964. Reassembled at Zhukovskiy, it was first flown there by P M Ostapenko on 9 September 1964.

It incorporated all the refinements introduced on the first preproduction reconnaissance aircraft, and in most respects was identical to the Ye-155R-3. Differences included a more capacious ogival nose tailored to the interceptor's radar (but actually occupied by instrumentation and ballast), and a larger wing with greater span and with chord extended at the front to give a leading-edge sweep of 42°30′ over the inboard half and 41°02′ from there to the tip. As originally built, the wings were horizontal. The fins were not sealed to form integral tanks. Provision was made for four underwing pylons, each secured by bolts in plates of 30KhGSNA steel. Only the outer pylons were installed, and on these were hung red-painted mockup K-40 missiles. A telemetry antenna was fitted under the fuselage behind the radome.

The Ye-155P-1 made most of the factory tests, and also gained some of the world records (*see* box, opposite). The second interceptor prototype, the Ye-155P-2, was built by the OKB in 1965. It lacked radar, the only visible difference being that the telemetry antenna was repositioned under the centre fuselage.

Ye-155P preproduction

Development of the interceptor posed unprecedented problems, one of which was the ability of these aircraft to cover great distances in a few seconds, making tracking difficult. The problem was compounded by firing trials with live K-40R missiles against high-speed targets. The missile had an effective range of 90km (56 miles), and in head-on engagements debris was scattered over an area 'hundreds of kilometres long and dozens of kilometres wide, much larger than the affordable area of the firing ranges'.

The preproduction batch, intended mainly to fly the State acceptance trials, comprised nine aircraft Ye-155P-3 to Ye-155P-11. All were built in the old OKB shop (Zenit factory), in cramped conditions; each had to be rotated nose-up on rollout in order for its fins to pass through the doorway. The State trials were flown by Aircraft 3, 4, 5, 6, 10 and 11, based at NII-VVS at Akhtubinsk. Aircraft 7, 8 and 9 were operated by the Mikoyan OKB at Zhukovskiy.

All nine carried test instrumentation, the first three in place of the radar. The Ye-155P-3 was the first to have radar, so from this aircraft onwards the instrumentation was in a ventral pod. Aircraft 3, 4 and 5 had an incomplete radar installation, which finally arrived with the Ye-155P-6. The *Smerch*-A (waterspout) radar was derived from the radar developed by the Volkov KB for the Tu-128. Features included a large Cassegrain antenna scanned mechanically ±60° in azimuth and 6° in elevation. Against a 16sq m target, the detection range was 100km (62.14 miles) and lock-on tracking half as great. It was specifically designed to have capability against low-altitude targets, and provided target illumination for the K-40R missile (*see* Appendix 2). A 2cm waveband was added to resist jamming. It was one of the last Soviet interceptor radars to be based on thermionic (vacuum) tubes.

All the preproduction aircraft had the four pylons installed. A further visible feature of the final seven aircraft, Nos. 5–11, was that on their wingtips were modified antiflutter bodies fitted with large symmetric delta fins above and below at the rear. Called 'webbed feet', these were intended to improve directional stability when the aircraft was fitted with all four missiles. At high speeds, firing missiles had caused severe yawing problems.

The Ye-155P prototypes were supported by many simulators and rigs,

The 'Ye-266' records

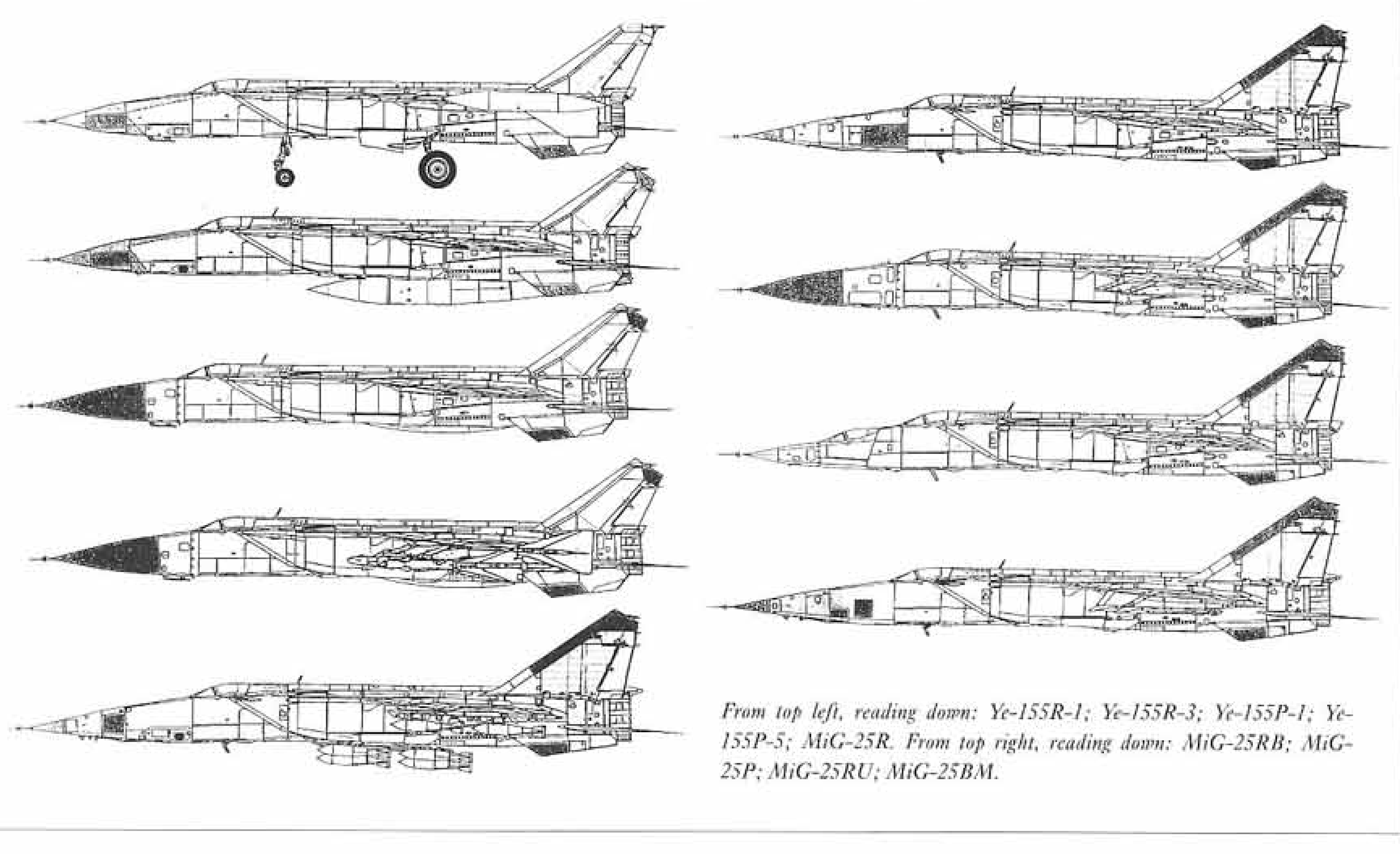
From the start of the programme it was obvious the Ye-155 had the potential to set world records. The difficulty was in getting hold of aircraft, all of which were committed to over eighty VVS and IA-PVO test programmes. The first records were set on 16 March 1965 by Fedotov flying the Ye-155R-2: speed of 2,319.12km/h over 1,000km circuit with payloads of 1,000kg and 2,000kg. The aircraft was 'Ye-266 powered by two R-266 turbojets of 10,000kg thrust'.

A high-level decree allowed four of these previously secret aircraft to fly past in the airshow at Domodedovo on 9 July 1967. All the OKB pilots were otherwise engaged on this occasion, so the aircraft were flown by NII-VVS pilots. First came V I Petrov flying the Ye-155R-3. Behind him was a formation of three: I I Lesnikov flew Ye-155P-1, G A Gorovoy flew Ye-155P-2 and G B Vakhmistrov flew Ye-155P-5. All carried conformal ventral containers of test instrumentation between the engines.

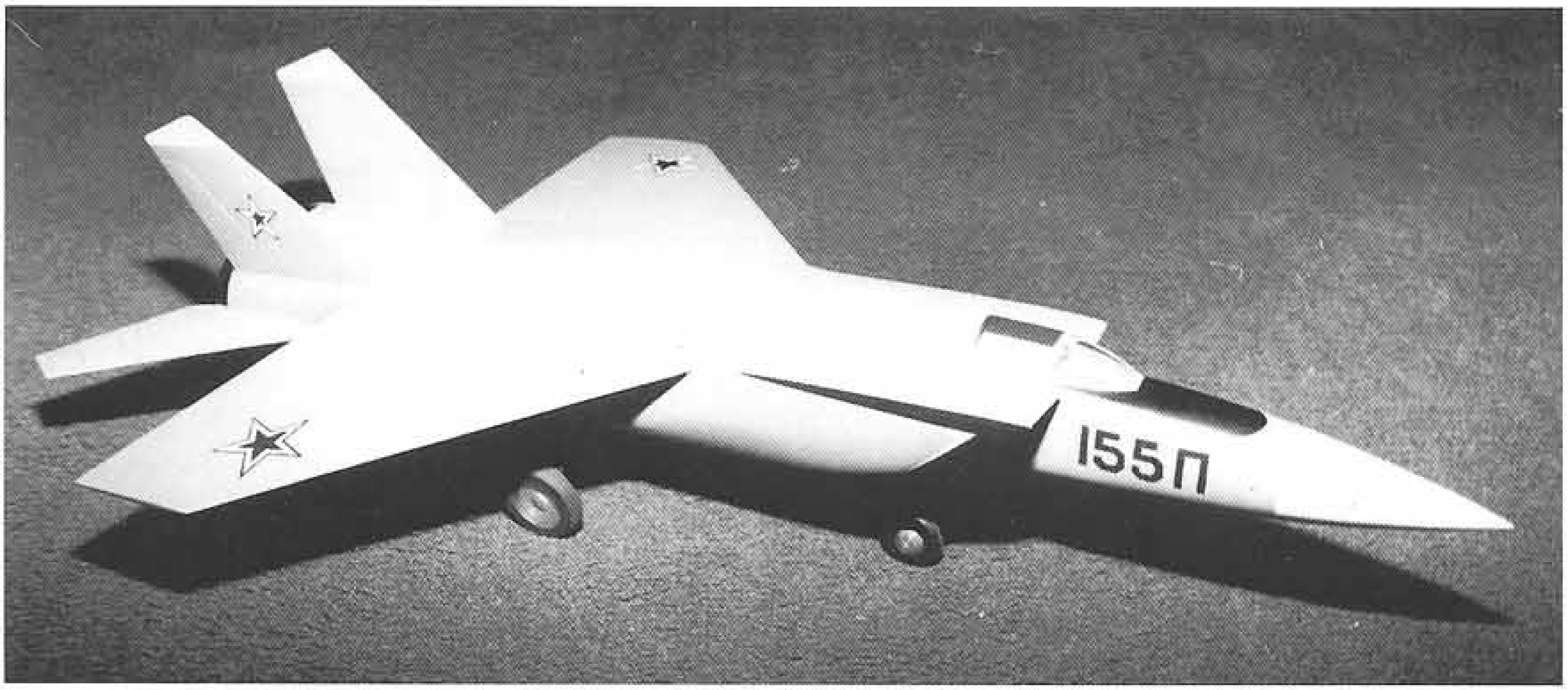
This cleared the way to the OKB test pilots setting records. Engineer Yu S Vygodskiy selected flight trajectories, assisted by the LII-MAP precision tracking network. The following were ratified:

5 October 1967, M M Komarov, 500km circuit 2,982.5km/h (1,864mph).
5 October 1967, A V Fedotov, 1,000kg payload 29,977m (98,349.7ft).
8 April 1973, A V Fedotov, 100km circuit 2,605.1km/h (1,628.1mph).
4 June 1973, B A Orlov, climb to 20,000m 2min 49.8sec.
4 June 1973, P M Ostapenko, climb to 25,000m 3min 12.6sec,
 and to 30,000m 4min 3.86sec.
25 July 1973, A V Fedotov, 1,000kg payload zoom to 35,230m (115,584ft).
25 July 1973, A V Fedotov, no payload zoom to 36,240m (118,897.6ft).

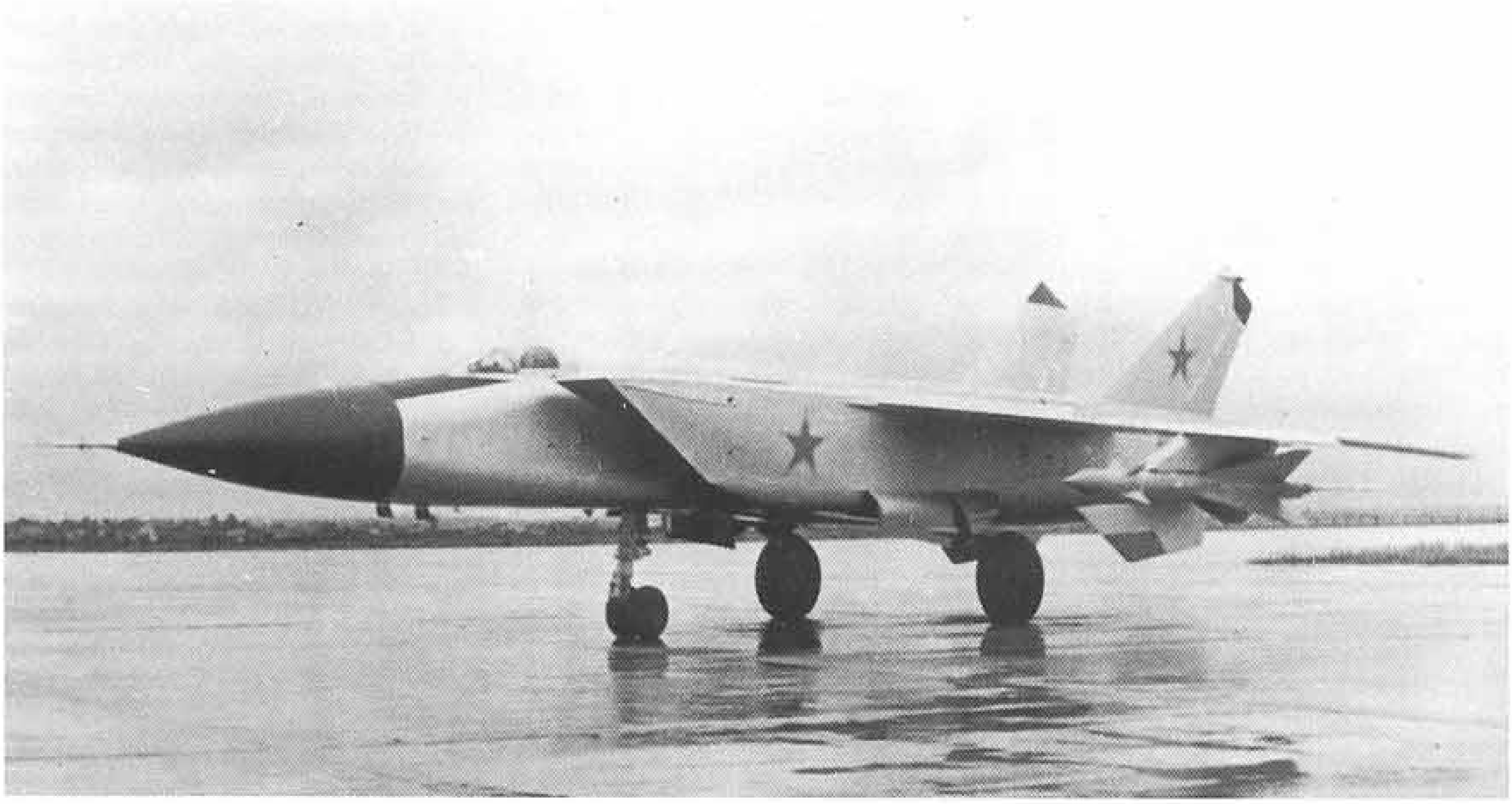
Precisely which aircraft achieved these records was classified until 1996. It was then discovered that they comprised the Ye-155R-1, Ye-155R-3 and Ye-155P-1, unmodified except for removal of a few items such as telemetry antennas. Today the Ye-155R-3 survives at the VVS museum at Monino, where this reconnaissance prototype has been given the missile pylons of the interceptor and the spurious code 'Red 25'.



From top left, reading down: Ye-155R-1; Ye-155R-3; Ye-155P-1; Ye-155P-5; MiG-25R. From top right, reading down: MiG-25RB; MiG-25P; MiG-25RU; MiG-25BM.



Ye-155P project model. (photograph by Yefim Gordon)



Ye-155P-1. (OKB)

and also by various test aircraft. Three Tupolev Tu-104s were used as radar testbeds and to help develop the navigation systems. The semiactive K-40R missile guidance was developed with a Tu-110. A piston-engined Ilyushin Il-14 served as a command relay and guidance aircraft, and a MiG-21US and Sukhoi Su-9 served as avionics testbeds.

Stage A (general flight tests) of the State acceptance trials began in November 1965. The State Commission was headed by Marshal Ye Ya Savitskiy, then deputy commander of the PVO. Stage B (complete weapon-system tests) was split into two parts. The first ended in 1968, resulting in a tentative clearance for production. The second part was completed in 1969, with 161 flights at Akhtubinsk and 51 at Zhukovskiy. A further 116 flights were made to calibrate systems and simulate missile launches, with aircraft 10 and 11 posing as targets. These two aircraft were also used to train the first regular VVS and PVO pilots.

During initial testing from NII-VVS Akhtubinsk 1,291 flights were made, including 693 in the State acceptance programme. During live missile tests 105 K-40R and K-40T missiles were fired at thirty-three targets of types Il-28M, Tu-16M, M-21, Yak-25RV-II and KRM (cruise missile conversion). A problem was aileron reversal caused by wing deflection in hard manoeuvres. Rather than redesign the wing, pilots were forbidden to exceed Mach 2.83 and 5g (though a MiG-25P at Kotlas survived 11+g). On 30 October 1967 I I Lesnikov, seeking a time-to-height record, lost control and crashed in the

Ye-155P-1. On 26 April 1969 the commander of the IA-PVO, Gen A L Kadomtsev, was killed in the Ye-155P-11 as a result of uncontained engine compressor failure while on his first check flight. At this time engine TBO was still only 25 hours, but it was later cleared to 750 hours.

A factor in the crash of Ye-155P-1 had been complete loss of roll authority. In a major programme by the OKB with the three aircraft at LII Zhukovskiy the tailplane control system was modified so that, at over 800km/h (497mph) IAS, the tailplanes could operate in opposition as tailerons, augmenting the power of the ailerons. This was expected to solve the problem, but on 30 June 1969, practising for an airshow at Kubinka, Weapons School pilot Maystrenko was killed by an apparently uncommanded roll at low level. Investigation showed no precrash failure, and theories ranged from windshear to pilot error. Then reports of sudden roll-control failures started to come from PVO regiments, and VVS test pilot Kuznetsov was killed in similar circumstances. On 4 October 1973, investigating these accidents with an instrumented aircraft cost the life of LII pilot Oleg Gudkov, but showed the answer. At high IAS it was possible for the overbalanced tailerons to exceed the power of the BU-170 actuator. Accordingly the taileron axis was moved forwards 146mm (5¾in). This was made standard.

The S-155 aircraft/missile interceptor system was cleared for service on 28 April 1970, the aircraft becoming the MiG-25P. To avoid breaking up the story, all interceptor versions will be described next, even though the first aircraft delivered was a MiG-25R.

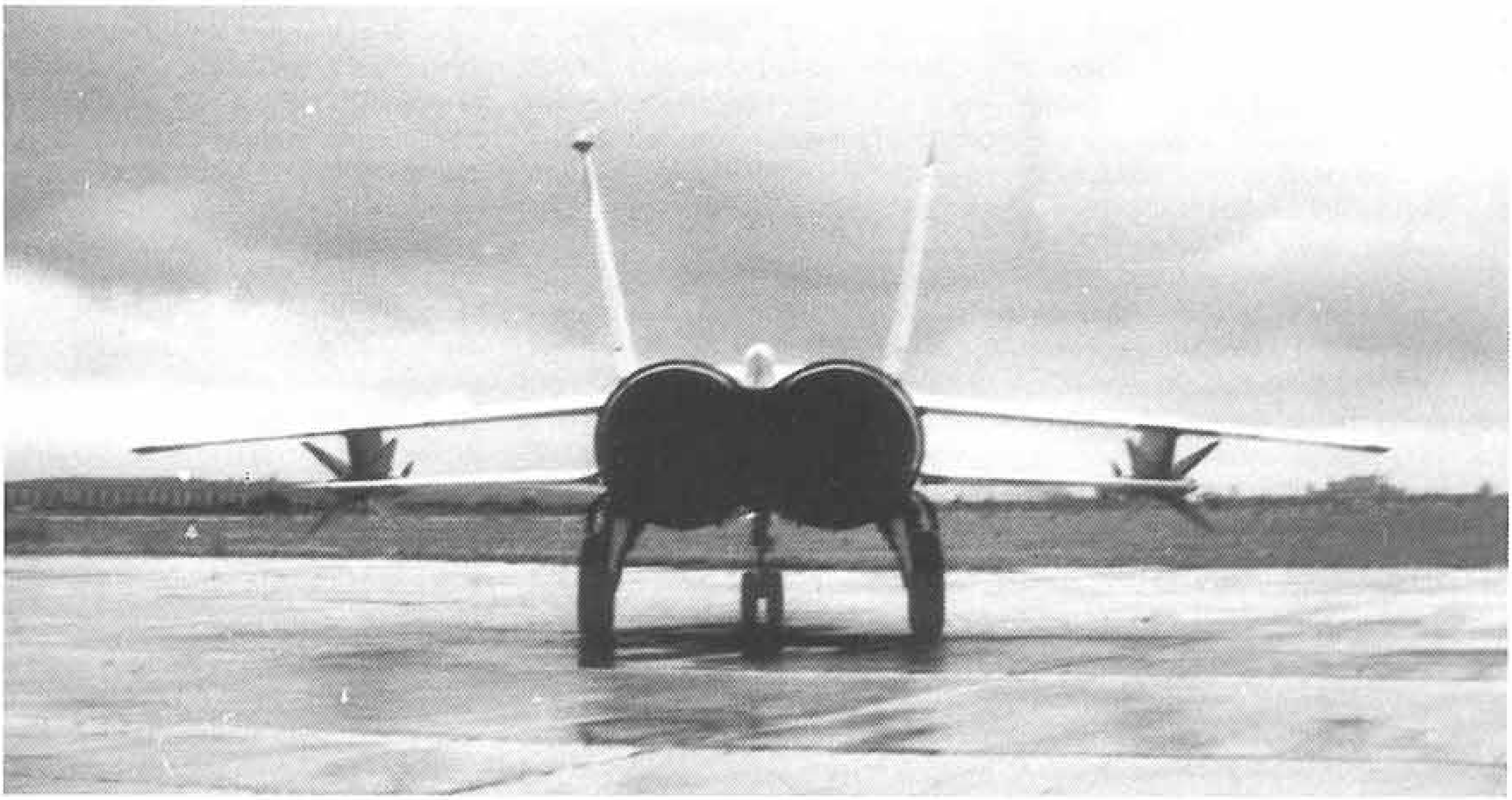
MiG-25P, 84

Though clearance for service was not received until 1970, the Gor'kiy factory continued low-rate output of the MiG-25P in 1969 following completion of the Ye-155P-11. This initial series had identical airframes, with horizontal wings, web-foot endplates and small tails. The first deliveries were made in 1969 to the PVO Fighter Weapons School.

Service tests were completed in 1970, in the course of which live firings were made on the NII-VVS test range with R-40R and R-40T missiles. Targets 'in the forward and rear hemisphere were successfully engaged at 20km at speeds up to 2,700km/h [1,688mph] showing the MiG-25 ... is capable of destroying the SR-71'.

With *Izdeliye* 84, the MiG-25P entered full production at the beginning of 1971. There were several major airframe changes. The wings were altered in detail, and set at 2° incidence with –5° anhedral. The fins were redesigned by moving the main vertical member from Frame 13 forwards to Frame 12, whilst keeping the trailing-edge root unmoved and leaving leading-edge sweep unchanged (except that a small dorsal fin was added ahead of the root). In effect this pulled the top of the fin forwards, so trailing-edge sweep was changed from 30° to 15°, but despite this the effect of adding so much area at the front also increased fin height, and increased the area of each surface by over 60 per cent to 8sq m (86.1sq ft). This enabled the height of the ventral fins to be halved, eliminating a previous problem of scraping on the runway, and it also enabled the 'web-foot' wing endplates to be discarded. The reduced fin sweep at the rear changed the shape of the rudders, and yaw dampers were added.

These changes enabled all MiG-25 versions to be cleared to an IAS of 1,300km/h (808mph), an increase of 200km/h. The main landing-gear legs were modified after one failed from intercrystalline corrosion when Ye-155P-3 was left fully fuelled overnight in winter. The electric starters were replaced by a self-contained gas-turbine APU starter, with dual high-energy ignition. The APU inlet under the fuselage was opened pneumatically and, after main-engine startup, closed hydraulically. The integral tanks were made more resistant to cracking caused by repeated heating



Ye-155P-1. (Yefim Gordon archive)

and cooling, and a method for welding hairline cracks was devised. No provision was made for external fuel.

The *Smerch*-A1 radar, also known as RP-25 and *Izdeliye* 720, was matched with the K-10T sight in the weapon control system. The radar could search autonomously or use ground inputs relayed via the *Vozdukh*-1 command link. After that, target lock-on, aircraft guidance to a firing position and data feed to the missile warhead occurred automatically. In 1970 the radar was made more resistant to ground clutter and jamming, and a waveguide was added to synchronize the waveforms of the radar and the selected missile until launch. Each pylon was fitted with an APU-84-46 launcher (aircraft 84, missile 46). Normal weapon load was two R-40R (*Izdeliye* 46R) and two R-40T, distributed symmetrically.

Basic avionics were common to all versions. They included R-832M *Evkalipt* (eucalyptus) uhf radio, R-802 vhf radio, R-847RM (later R-864) hf radio, ARK-10 radio compass, RV-19 (later RV-18) high-altitude radar altimeter, RV-4 (later RV-4A) precision radar altimeter for landing in 50m (164ft) minima, *Sirena*-3M (siren), later replaced by the LO-06 *Beryoza* (birch) RWR, MRP-56P marker receiver, SO-63B (later SO-69) ATC transponder, SRO-2P IFF transponder, *Pion*-3P (peony) antenna feeder, SPU-7 intercom, RSBN-6S *Korall* (coral) Shoran navaid, PVD-7 air-data/pitot probe, *Tester*-UZL flight-data recorder, P-591 cockpit voice recorder and an RI-65 tape recorder with autotransmit to ground stations. Interceptors were fitted with the SAU-155P1 automatic flight-control system, SKV-2N-2 (later SKV-2NL-2) course system and SVS-PN-5 data link forming part of *Polyot*-1I. In early MiG-25Ps the ground command link was *Lazur* (azure).

Other versions are described later. Following equipment of the IA-PVO Fighter Weapons School at Moscow Kubinka, the MiG-25P was delivered to a regiment near Gor'kiy, and then to Kiev, Perm, Baku, Rostov and to several bases in the North and Far East. Overhaul shops were set up at Nasosnaya (near Baku) and at the large overhaul factory at Dnepropetrovsk. In 1975 the radar was upgraded to *Smerch*-A2 (720M), and from 1978 surviving aircraft were upgraded to MiG-25PD standard. The ASCC name was 'Foxbat-A'.

Span 14.015m (45ft 11¾in); length 21.42m (70t 3½in), (excluding PVD) 19.75m (64ft 9⅝in); wing area 61.4sq m (660.9sq ft).

Weight empty 20,020kg (44,136lb); fuel 14,570kg (32,121lb); loaded (clean) 34,920kg (76,984lb), (four missiles) 36,720kg (80,952lb).

Maximum speed (sea level) 1,300km/h (808mph), (13,000m/42,651ft) limited by decree to 3,000km/h (1,864mph, Mach 2.83); climb, see records; climb from rest to 20,000m (65,617ft) at Mach 2.35 8.9min; service ceiling 20,700m (67,915ft); range (subsonic, no tank) 1,730km (1,075 miles), (supersonic) 1,250km (777 miles); takeoff speed 360km/h (224mph); takeoff run 1,200m (3,937ft).

After the spate of incidents caused by aileron reversal and tailplane overbalance the MiG-25P settled down well. Its structural strength was shown by the pullout at over 11g previously mentioned, when an inexperienced pilot let the radar lock on a target on the ground. On another occasion a missile fell off on a landing approach and killed a cow, and on another a pilot landed in bad weather following loss of almost all electrics caused by a faulty distribution bus. Over 15 years aircraft TBO rose from 50 hours to 1,000 hours.

According to the PVO 'Units stationed in border areas successfully intercepted [Lockheed] SR-71As, the weapon system correctly indicating "ready for launch". This signal is not given unless speed, altitude, range, g-load and triangulation errors are all suitable, and the missile warhead is locked on. The only reason the Blackbirds were not shot down is because the actual order to fire was not given.'

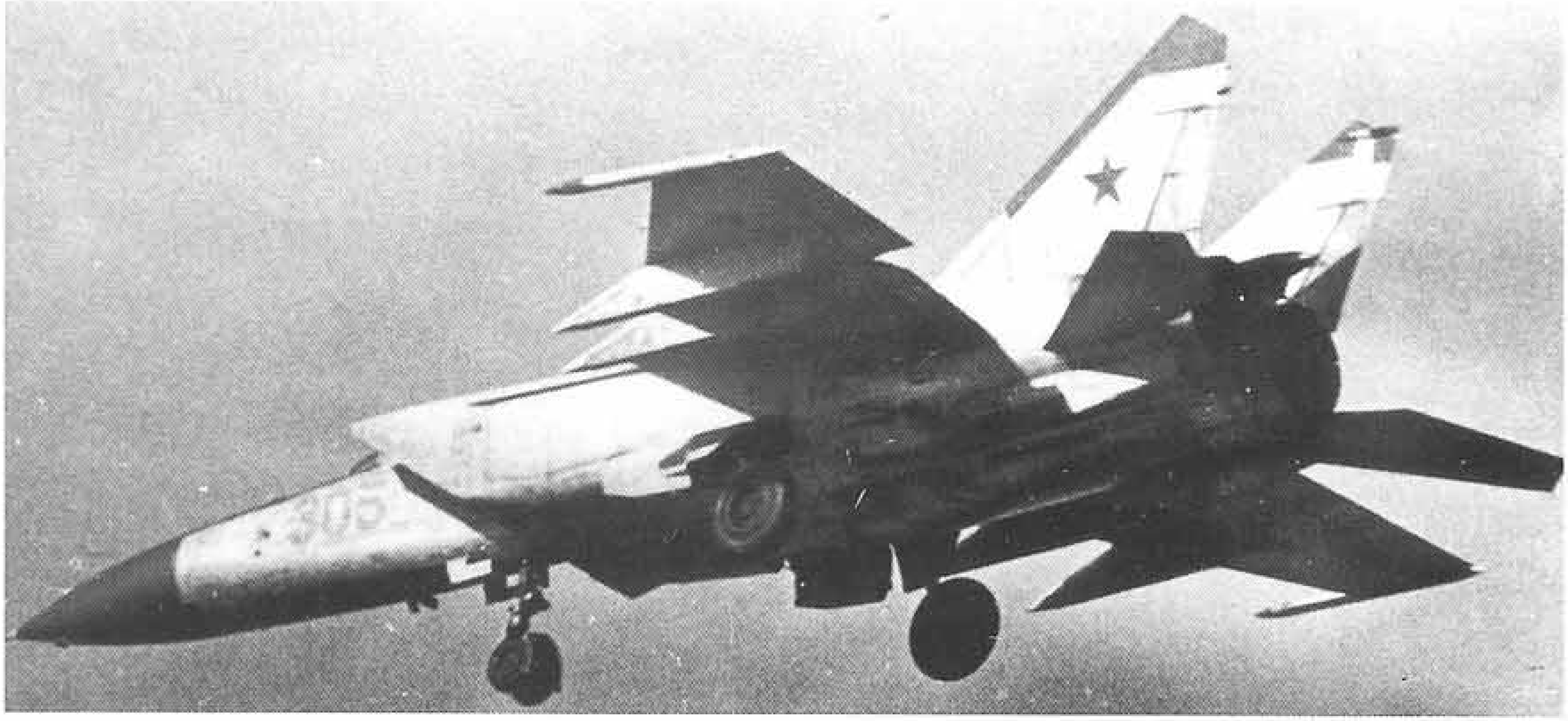
In the early 1970s an improved ground command system, *Vozdukh*-1M, was introduced. A series aircraft was used to test the *Parol*-2 (password) IFF system, comprising a 632-1 transmitter and 620-20P receiver. From one of the first series aircraft (Factory No. 840SCh09) the blown flaps were replaced by plain flaps lowered only to 25° for landing. In 1971 the nosewheels were modified and fitted with a mudguard at the back which, on retraction, formed a slight blister under the fuselage. Immediately ahead of this a prominent blade antenna was added for R-832M uhf, and later aircraft featured LO-06 warning antennas on the sides of the inlets. Early in production the seat was changed to the KM-1M, usable from 130-1,200km/h IAS and from ground level to 20,000m. By 1976 the radar was being upgraded to *Smerch*-A3, with an A4 version about two years away, but by this time it was essential for the radar to detect small targets among ground clutter, which a low-p.r.f. (pulse-recurrence frequency) monopulse radar was incapable of doing.

In any case the need for a major update was accentuated on 6 September 1976 when, without having been detected by Japanese air-defence radars, a MiG-25P landed at Hakodate airbase. Pilot Viktor Belenko said he sought asylum in the USA. Though the aircraft was returned, it was obvious it would be minutely studied by Americans beforehand. Accordingly plans for a major weapons-system upgrade were accelerated, while the IA-PVO set about replacing *Vozdukh*-1M with the completely new *Luch*-1 (ray) ground guidance system, capable of aligning the optical axis of the aircraft's radar with the target, making the radar almost immune to jamming.

MiG-25PD, 84D

The improved interceptor was designated MiG-25PD or *Izdeliye* 84D (*dorabotannyi*, upgraded). Work proceeded quickly, thanks to careful preparation by the OKB project chief N Z Matyuk and L G Shengelaya. The basis of the new weapons system was the *Sapfir*-25, or S-25, developed by Yu Kirpichnikov's KB from the S-23 quasi-CW (continuous-wave) radar of the MiG-23 family. It differed physically from the S-23 in having an enlarged antenna dish, and it offered much better discrimination against low-altitude targets. Detection range against a 16sq m target rose well beyond 100km (62.14 miles). The radome was unchanged, but it had to be moved forwards 25cm (9⅞in) to accommodate an extra bay demanded by the radar, whose access doors were also quite different.

To match the greater detection range of the new radar the missiles were fitted with new homing heads (both the radar and IR versions) and increased-capacity batteries. The new missiles were designated R-40RD and R-40TD. In technical manuals the radar was designated RP-25M and the missiles *Izdeliye* 46RD and 46TD. To make the new system less susceptible to ECM,



MiG-25PD 'Blue 305'. (photograph by Viktor Drushlyakov)

and even enable interceptions to be made with the radar in standby mode, an IRST (infrared search/track) was installed. This was first tested in the second PD, callsign 'Blue 306' (the first was '305'), in which the development 62Sh-1 IRST was fitted in a small gondola under the fuselage immediately behind the radome, with heat-resistant forward windows. Series aircraft had the TP-62Sh.

Thanks to ceaseless effort by Tumanskiy an uprated engine was available, the R-15BD-300. This had dry and afterburning ratings of 8,800kg and 11,200kg (19,400lb and 24,691lb), respectively. It was fitted with longer hinged flaps in the convergent/divergent nozzle, and the main gearbox had a constant-speed drive to alternators supplying the accurately controlled 400Hz three-phase power needed by the new radar.

To cooperate with the *Luch*-1 system the MiG-25PD was equipped with the new BAN-75 guidance and target indication system, replacing the *Lazur*. A further update was to make provision for the 5,300lit (1,165gal) external tank, as used on the reconnaissance versions. Another was the tubular housing for the cruciform braking parachutes, made of *Tekstolit* fibre-reinforced composite. The air-data boom on the nose was simplified by omitting the vanes sensing airstream direction. Not least, the outboard pylons were modified so that, as the usual fit, they would take a twin APU-60-II launcher for a pair of R-60 or R-60M agile short-range missiles, instead of a single R-40TD.

The MiG-25PD was produced in 1978–82, after which the Gor'kiy factory switched to the MiG-31. In service it proved extremely reliable. One was shot down when it got in the way of an R-60 fired by its wingman, and another was lost when the radome disintegrated at very high speed. A few, including 'Blue 45', were fitted with a retractable inflight-refuelling probe in an extra bay added between the radar and Frame 1 at the windscreen. Lack of suitable tankers prevented this becoming standard. In 1990 eighty-one were based in Ukraine, and in 1997 twenty-seven were still operational, with seven more stored.

Operational experience showed that the MiG-25PD was fully capable of intercepting small targets flying only just above the ground, but this was considered to make the aircraft vulnerable to enemy fire. To offer protection the second series aircraft, '306', was fitted with an ECM pack in a large but shallow ventral bulge and IRCM flare dispensers. It was designated MiG-25PDSL.

The addition of the IRST in the MiG-25PD changed the appearance, and so resulted in the ASCC name of 'Foxbat-E'.

Dimensions unchanged except length 21.67m (71ft 1⅛in).

Weights not discovered.

Performance unchanged except range with tank about 2,400km (1,491 miles).

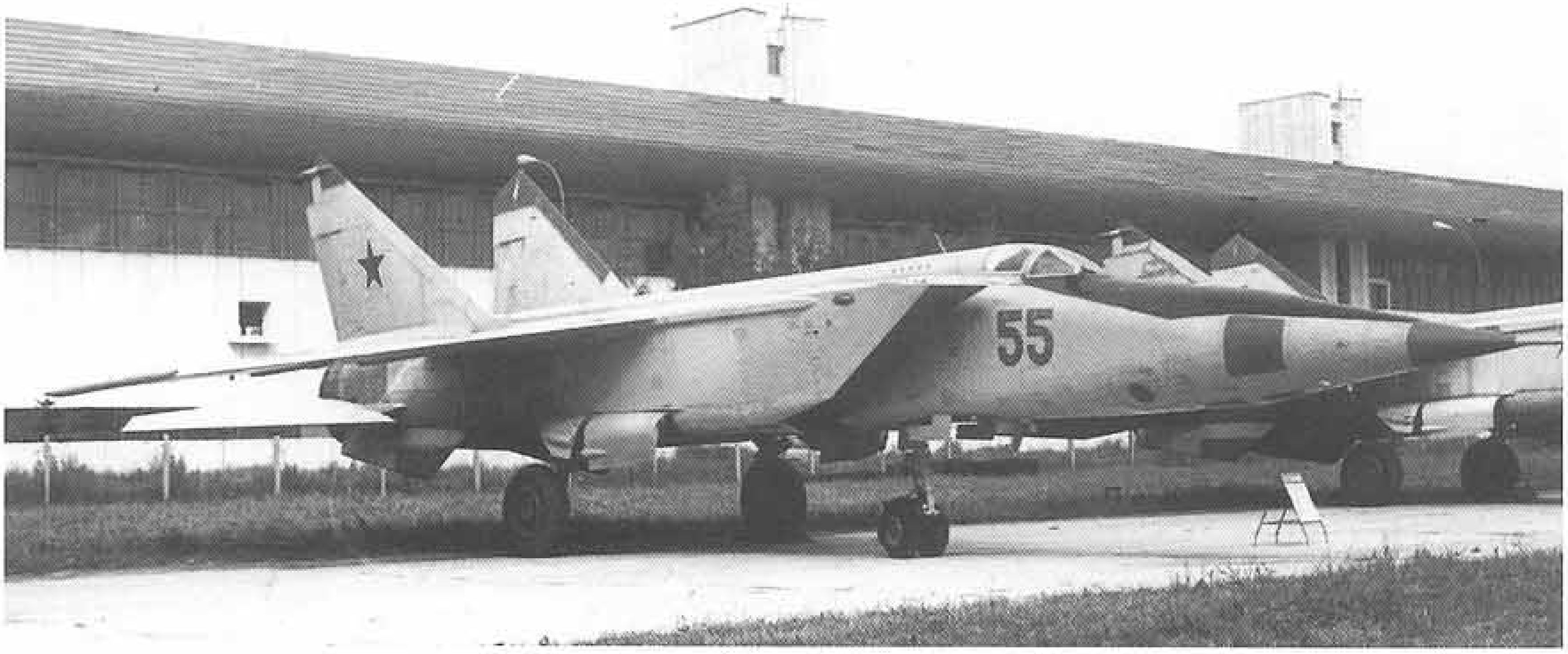
MiG-25PDS

Owing to the substantial improvement in interception capability afforded by the MiG-25PD the Mikoyan OKB made the unprecedented decision to upgrade all MiG-25P aircraft in service to this standard. The modification programme began in 1979, and was done at Gor'kiy, assisted by the Dnepropetrovsk repair factory. Each upgraded aircraft was redesignated MiG-25PDS (*perekhvatchik dorabotannyi v stroyu*, interceptor upgraded in service). The programme involved about 370 aircraft.

Each was almost identical to a MiG-25PD, except for minor deficiencies. There was no provision for the drop tank, and the braking parachute installation remained the original, with a duralumin container ending in a diagonal knife-edge.

MiG-25PD export

When the MiG-25P entered front-line service it was secret. It was not flown by VVS units stationed in Warsaw Pact countries, and not even considered as a product for export. By 1976 the situation had changed – not only because of Lt Belenko's defection – and at the request of Libya an export version was agreed. Though called MiG-25PD, most are nearer in capability to the MiG-25P, with *Smerch*-A2 radar, but with APU-60-11 interfaces for paired R-60M missiles. The braking parachutes were the improved cruciform type in a tubular compartment with a bullet-like end. Export customers



MiG-25RB. (photograph by Yuriy Popov)

included Algeria (20), Iraq (20), Libya (65) and Syria (30). These aircraft saw action in several local conflicts.

MiG-25R, 02

As noted, both the first prototype MiG-25 and the first production aircraft were of the reconnaissance version, the latter flying in 1969. The basic features of this version have already been described. Early aircraft (Series 3 and 4) were delivered to the Lipetsk training centre for pilot and ground-staff training and operational evaluation. Next deliveries went to the Guards Independent Reconnaissance Regiment at Shatalovo near Smolensk. This unit was tasked with the service-test programme.

The MiG-25R, *Izdeliye* 02, was initially equipped with a *FOTINT* suite comprising four oblique A-70M cameras and a single A/E-10 topographic camera with a focal length of 1,300mm (51.2in). These were developed under A Beshenov at the Zenit Optics plant in Krasnogorsk. They looked through five windows of the type already described, and were cleared for use at 22,000m (72,178ft). Four FotAB-100-80 flare bombs could be carried in pairs under the wings, and four more in pairs under the fuselage.

The engines remained R-15B-300, the autopilot was the SAU-155R1, and the automatic course system the SKV-2N-1. Early aircraft had the KM-1 seat, but this was later replaced by the KM-1M. Up to Factory No. (F/n) 020ST03 ordinary wingtips were fitted, later aircraft having anti-flutter 'balance booms'. Up to F/n 020SL04 blown flaps were fitted, subsequent aircraft having 25° plain flaps. Early aircraft had *Sirena*-3M RWR, later replaced by L006 *Beryoza*. All surviving aircraft were later brought up to MiG-25RB standard. The ASCC name was 'Foxbat-B'. Data basically as MiG-25RB.

MiG-25RB, 02B

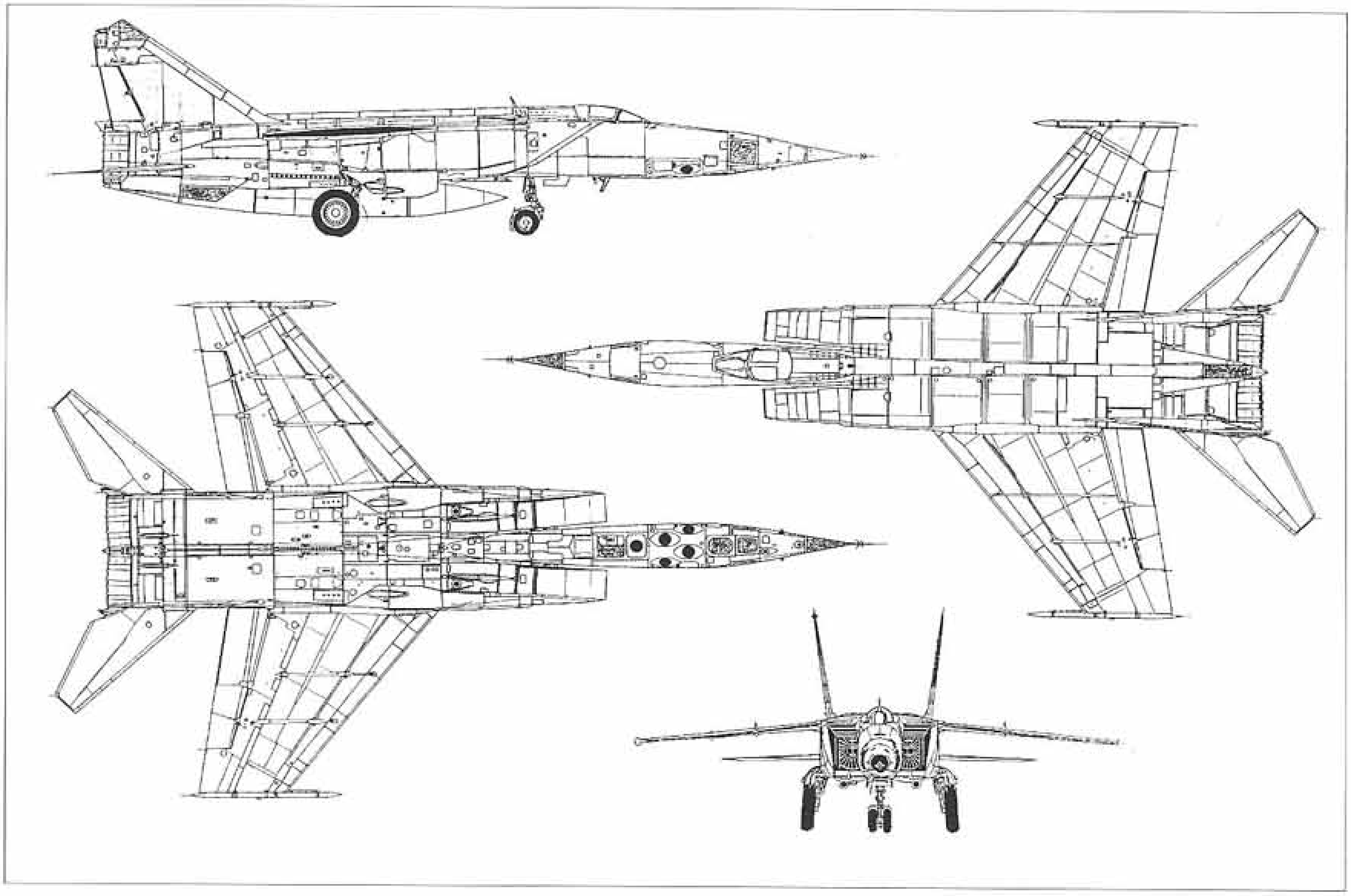
After defeating the Arab states in the 1967 Six Day War, Israel, with American backing, systematically bombed Egyptian military bases and industrial centres. When Cairo's electricity supply was knocked out Egypt asked the USSR for help in air defence, reconnaissance and strike. Soviet leaders, notably Defence Minister Marshal D F Ustinov, decided that, as it carried large flare bombs, there was no reason why the MiG-25 should not become a dual-role reconnaissance bomber. Thus in late 1969 the Mikoyan OKB and related organizations were asked to produce the MiG-25RB, *Izdeliye* 02B, within four weeks.

To increase delivery accuracy the RSBN-6 (Shoran) was arranged to feed into the *Peleng* navigation system, and a programme for bomb travel was fed into the *Orbita* computer. A bomb-release system was devised, with MBDZ-U2 MERs (multiple ejection racks) with DZU-1 heat-resistant bomb shackles, and safe bomb temperatures were calculated. A group was formed to evaluate aircraft survivability, including Yu F Polushkin (OKB) and A G Zaitsev (GosNIIAS). Early aircraft had two fuselage MERs carrying four FAB-500M-62 bombs, a load of 2,000kg (4,409lb). Later one was added under each wing, giving the option of eight M-62 (regular) or M-62T (heat insulated) bombs, a load of 4,000kg (8,818lb), or combinations of FAB-250 bombs and FotAB-100-80 flare bombs.

Supervised by A V Minayev (who later left Mikoyan to become Deputy Minister of Aircraft Industry), testing began at Akhtubinsk in February 1970, initially with the converted Ye-155R-4, code 'Red 024' (*Izdeliye* 02, airframe 4). In March Mikoyan pilot A G Fastovets made the first drop, from 20,000m (65,616ft) at 2,500km/h (1,563mph), a world first. Later NII-VVS pilots Col A S Bezhevets and N I Stogov took over.

Problems ranged from incorrect soldered wire joints, which melted in flight, to *Peleng* lapses when following ground beacons. The underwing region proved hotter than prediction. In April 1970 the *Peleng* failed, so Bezhevets had to switch to an alternate test mission. This involved prolonged supersonic flight, and the MER cartridges overheated and fired, causing uncommanded random bomb release. Wing bombs were not loaded until new cartridges were developed, together with the heat-insulated FAB-500M-62T bomb. These were then cleared on the wing racks to Mach 2.35.

With a bomb load, ceiling was naturally decreased, and the OKB restored the lost altitude by increasing the area of the upper surface of the



MiG-25RB (tank in side view only).

inlet ducts. With a 4,000kg bomb load, ceiling was increased by 700m (2,296ft) without affecting speed or range. The Gor'kiy plant was then told urgently to convert MiG-25R aircraft to RB standard, and also to switch to producing the RB exclusively. These were fitted with an improved *Peleng*-D complex, with a more accurate INS (inertial navigation system) using floating gyros (*Anis* had ball-bearings), as well as inputs from a hyperbolic Loran system and a vertical accelerometer for making release-point corrections. For precision release on preset coordinates later aircraft were equipped with *Peleng*-DR or -DM.

Akhtubinsk was faced with a major effort, not only in systems debugging and pilot training but also in establishing optimum climb/cruise transition modes and turn trajectories after bomb release. The MiG-25RB was first issued to units in Ukraine, becoming operational in December 1970. It was certified for clear-weather day/night Photint, general-purpose and detailed Sigint, VFR/IFR day/night radar imaging and VFR/IFR day/night bombing. Reconnaissance limits were 23,000m (75,460ft), 3,000km/h (1,875mph) and 920km (575 miles) radius. Bombing limits were 21,000m (68,897ft), 2,500km/h (1,553mph) and 650km (406 miles) radius.

The normal camera fit was the same as the MiG-25R, but alternatives comprised two A-72 cameras (150mm, 5.9in, lens) for detailed study of a narrow strip, or an A-87 (650mm, 25.6in). For Sigint an SRS-4A (*Izdeliye* 30A) or SRS-4B (*Izdeliye* 30B) could be carried. Standard fit included a *Siren* (lilac) ECM pack, *Izdeliye* 141. From F/n 02022077 (No. 77) bomb load was increased to 5,000kg (11,023lb) by fitting tandem triplets under the fuselage and tandem pairs under the wings (*see* drawing). It was soon decided this load was excessive. At about the same time the fin tanks were deleted. Without fuselage bombs the drop tank (now regarded not as 5,300 but as 5,280 litres, 1,161gal) could be carried; it was seldom dropped, though it had a significant effect on drag.

The MiG-25RB was produced in 1970–72. Some trained pilots and mission specialists at Lipetsk, and five regiments were stationed in Poland and the German Democratic Republic. Later aircraft served in the Belorussian, Transcaucasian, Middle-Asian, Siberian and Leningrad military districts. In 1971 four were flown by Antonov An-22 to Egypt, where they were reassembled and flown over Israel by three VVS pilots, two NII-VVS and one Ministry of Aviation Industry. The aircraft was very popular, and was often used for rapid coverage of civilian floods, forest fires and similar events. In 1997 Ukraine still operated fifteen of the sixteen based there in 1990. The ASCC name was 'Foxbat-B'.

Span 13.38m (43ft 10¾in); length 23.2m (76ft 1⅜in), (excluding PVD) 21.55m (70ft 8½in); wing area 58.9sq m (634sq ft).

Weight empty 20,755kg (45,756lb); fuel (internal) 15,000kg (33,069lb), (tank) 4,450kg (9,810lb); weight loaded (clean) 35,060kg (77,293lb), (four FAB-500) 37,210kg (82,033lb), (tank, no bombs) 39,830kg (87,809lb).

Maximum speed (clean, over 18,000m) 3,000km/h (1,864mph, Mach 2.83); IAS limit (four FAB-500) 1,000km/h (625mph) to 5,000m, 1,100km/h (683.5mph) 5,000–15,800m, Mach 2.35 for 15min above 15,800m; IAS limit (tank) 1,000km/h (625mph) to 11,000m, Mach 1.5 above this level; maximum cruising speed (four FAB-500) 2,500km/h (1,553mph); climb to minimum combat altitude of 20,200m with four FAB-250 8.2min; over-target height with four FAB-250 20,700m (67,913ft); practical sustained ceiling (clean) 26,000m (85,300ft); combat radius (four FAB-500, correction for bomb travel) 560km (348 miles), (reconnaissance, no tank) 675km (419 miles), (with tank) 920km (572 miles); range (tank) 2,900km (1,802 miles), (at Mach 2.35, no tank) 2,045km (1,271 miles), (1,000m, 800km/h, four FAB-500) 1,017km (632 miles); endurance at Mach 0.92 (clean) 2hr 26min, (tank) 3hr; takeoff run (clean) 1,050m (3,445ft), (four FAB-500) 1,250m (4,100ft); unstick speed (clean) 350km/h (217mph), (four FAB-500) 375km/h (233mph); landing speed (clean, 23t) 280km/h (174mph); landing run 750m (2,460ft), (no parachute) 1,450m (4,757ft).

Ye-155PA project

In the mid-1960s the OKB planned this aircraft as the prototype of a derived interceptor with significantly higher performance. Powered by two R-15BV-300 engines, with considerably greater thrust at high altitude (V for *vysotnyi*, high altitude), the proposed MiG-25PA was to be capable of intercepting targets flying at 3,500–4,000km/h (2,175– 2,486mph) from distances of 100– 30,000m (328–98,425ft). It was to be equipped with the *Smerch*-100 radar and R-100 missiles. The need for extreme high-altitude performance faded, but the radar was eventually developed into the SBI-16 *Zaslon* for the MiG-31.

MiG-25 with MiG-29 system project

Experience gained in local wars gave rise to the idea of fitting the MiG-25 interceptor with the weapons system of the MiG-29. It was proposed to install a Fazotron *Topaz* radar with a new antenna reflector 30 per cent larger. The project foundered because the associated R-27 missile was not designed to absorb the intense kinetic heating at MiG-25 speeds.

MiG-25PU, 22

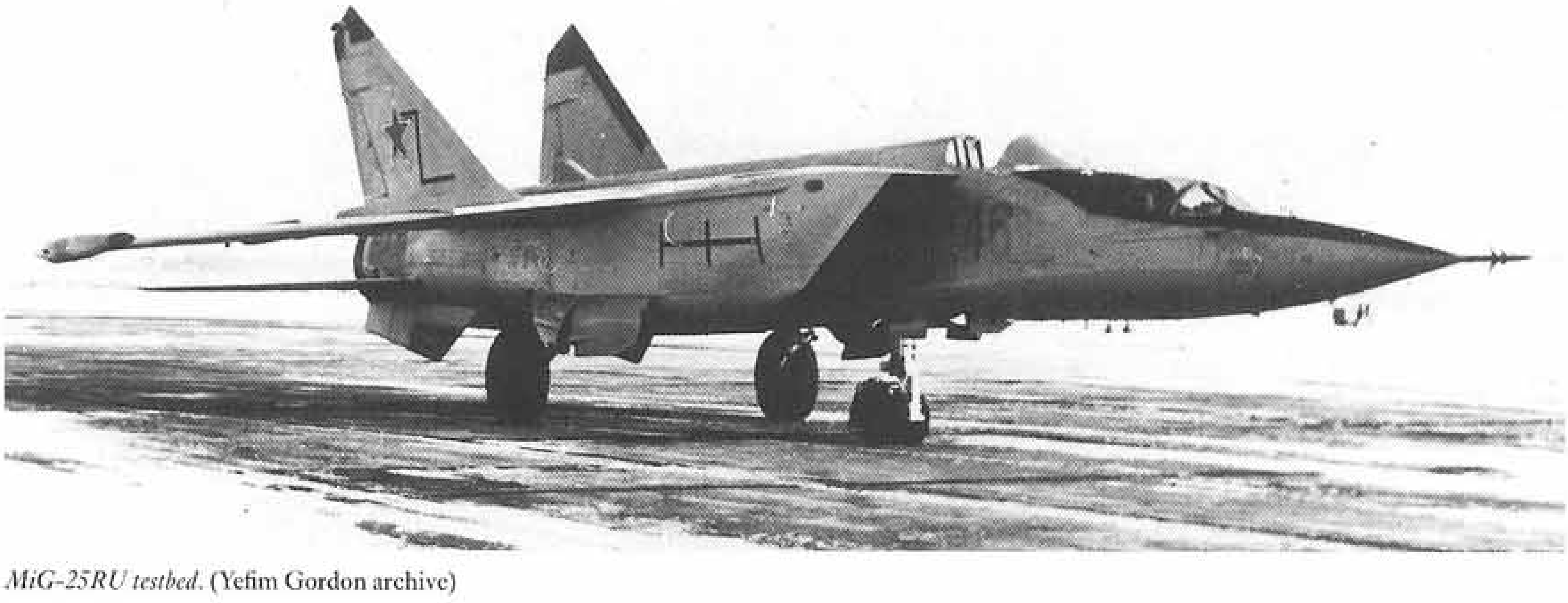
This dual-control trainer version was developed by the OKB in 1968 in response to pressure from VVS and PVO test pilots and instructors, who asked for trainers for both the P and R roles. Such aircraft had not been envisaged by the initial operational requirement, nor required by a government directive. The designers, under lead engineer A B Slobodskiy, chose the obvious stepped tandem layout, with the pupil in the original cockpit and the instructor in a new front cockpit at a lower level replacing the radar. This arrangement gave both occupants an excellent view, and had already been used for the Yak-28U and Tupolev Tu-128UT. The instructor had a failure simulation panel.

The most urgent demand came from the PVO, so the prototype was converted from a standard interceptor, with the large kinked-edge wing with four pylons. The interceptor trainer was designated MiG-25PU (*perekhvatchik uchebnyi*), and received factory code 22. The prototype was given the totally nonstandard callsign 'Blue U01', and flew in 1969. The only flight-test problem was buffeting at high Mach numbers, and rather than make design changes the Mach number was limited to 2.65. After State trials the MiG-25PU entered production at Gor'kiy. The rear cockpit was almost identical to that of the PD interceptor, and equipment included a radar simulator and four dummy R-40 missiles.

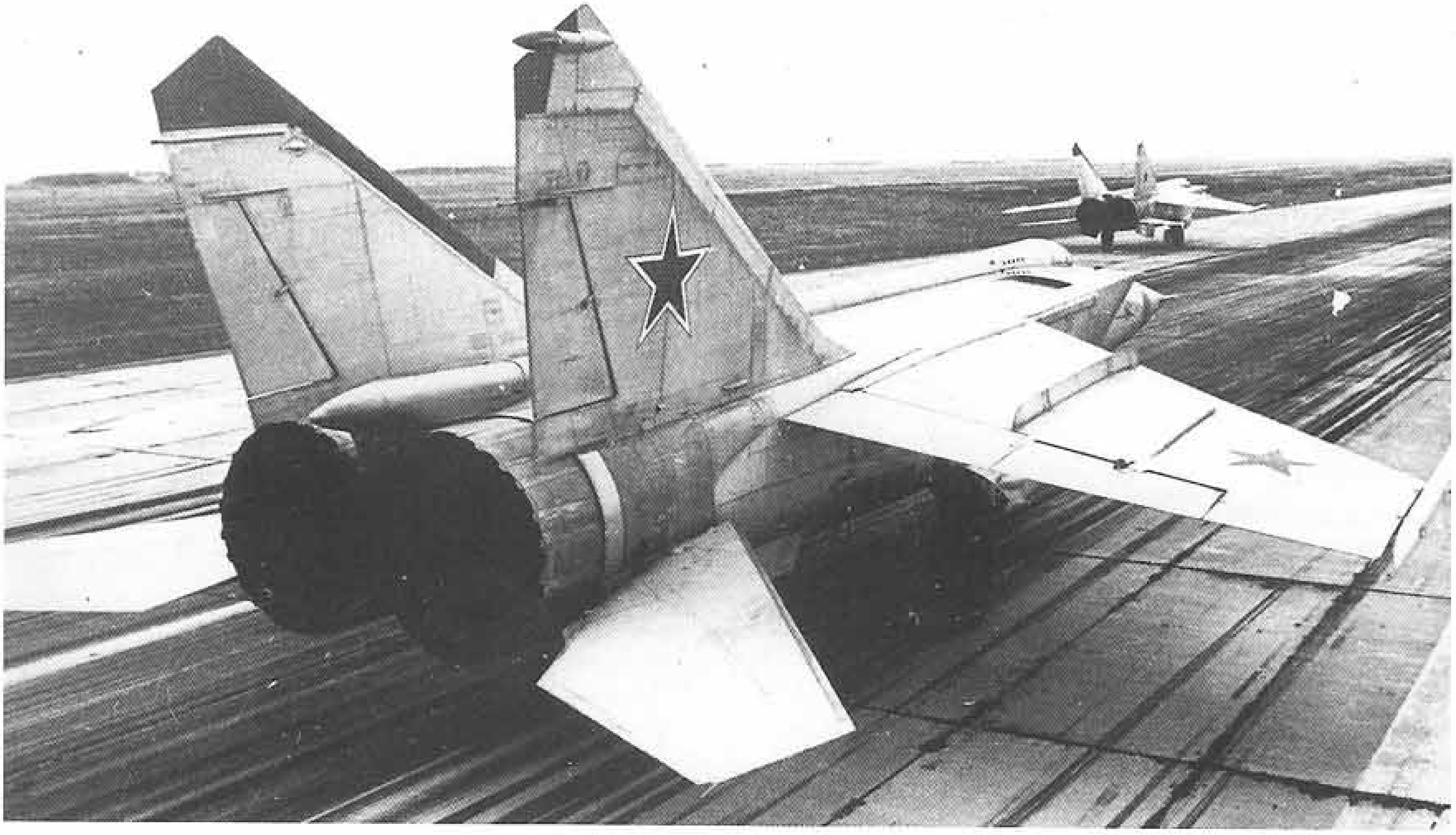
In 1977 Svetlana Savitskaya, world female aerobatics champion and daughter of Marshal Ye Savitskiy (who had been chairman of the MiG-25 State commission) graduated from the Zhukovskiy test-pilot school and trained on the MiG-25PU. It was decided to let her set female records without transitioning to the single-seater. On 31 August 1977 she set an altitude record of 21,209.9m (69,586.2ft). On 21 October she set 2,466.31km/h (1,532.5mph) round a 500km circuit. On 12 April 1978 she set 2,333km/h (1,449.7mph) over a 1,000km circuit. These records were reported as having been set by a 'Ye-133'. All MiG-25 trainer versions received the ASCC name 'Foxbat-C'.

MiG-25RU, 39

The OKB developed this second trainer version to meet the demand from VVS reconnaissance/strike units. The prototype, F/n 390SA01, made its first flight at Gor'kiy on 20 March 1971, flown by factory test pilot El'kinbard. As it was based on the MiG-25PU it had the wings of the interceptor, though no pylons were fitted. The aircraft also lacked the *Peleng* complex and reconnaissance equipment, though missions could be simulated. In service the main problem was accelerated fatigue caused by frequent application of severe loads and far more rapid buildup of supersonic time than other



MiG-25RU testbed. (Yefim Gordon archive)



MiG-25RBK. (Yefim Gordon archive)

versions. This required changes in manufacturing technology and in overhaul procedures.

The two trainer versions were produced in significant numbers, and a few were exported to MiG-25 operators. Examples have been used not only for pilot conversion and repeated proficiency training but also for weather reconnaissance and for various test programmes, as described later.

Span 14.015m (45ft 11¾in); length (excluding PVD) 21.40m (70ft 2½in), (fuselage only) 19.431m (63ft 9in); wing area 61.40sq m (660.9sq ft).

Weight empty 18,900kg (41,667lb); loaded (Tanks 3, 4 and wings) 26,700kg (58,862lb), (all tanks except Tank 1) 32,100kg (70,767lb), (full internal fuel) 34,460kg (75,970lb), (with drop tank) 39,200kg (86,419lb).

Maximum speed (sea level) 1,200km/h (746mph), (13,000m/42,651ft) 2,820km/h (1,752mph, Mach 2.65); takeoff unstick speed 350km/h (218mph); landing speed 290km/h (180mph).

MiG-25 testbeds

More than one hundred MiG-25 aircraft were used in various research, test and development programmes. The MiG-25R and RB proved to be particularly suitable for conversion into avionics and systems testbeds because the entire nose was covered by access doors, and it was relatively simple to replace the cameras and Sigint pallets by experimental avionics and instrumentation. The first RB converted at LII Zhukovskiy was called Project *Trapetsiya* (trapeze), used to test the navigation system of a new cruise missile.

MiG-25RBK, 02K

Though the Sigint equipment carried by the MiG-25R and RB could detect pulse-doppler radars, it could not transmit data on such radars to ground stations. Accordingly, in 1971, to meet VVS requirements Mikoyan developed a derivative of the MiG-25RB fitted with the *Kub*-3 (cube). This Sigint could pinpoint the location of both PD and CW radars, define their characteristics, and relay intelligence by data-link whilst recording it digitally for later analysis. Weighing several hundred kilograms, the *Kub* was too unwieldy to install on a quick-change pallet, as was SRS-4. Accordingly the aircraft nose had to be redesigned, and some cameras omitted and their ports faired over.

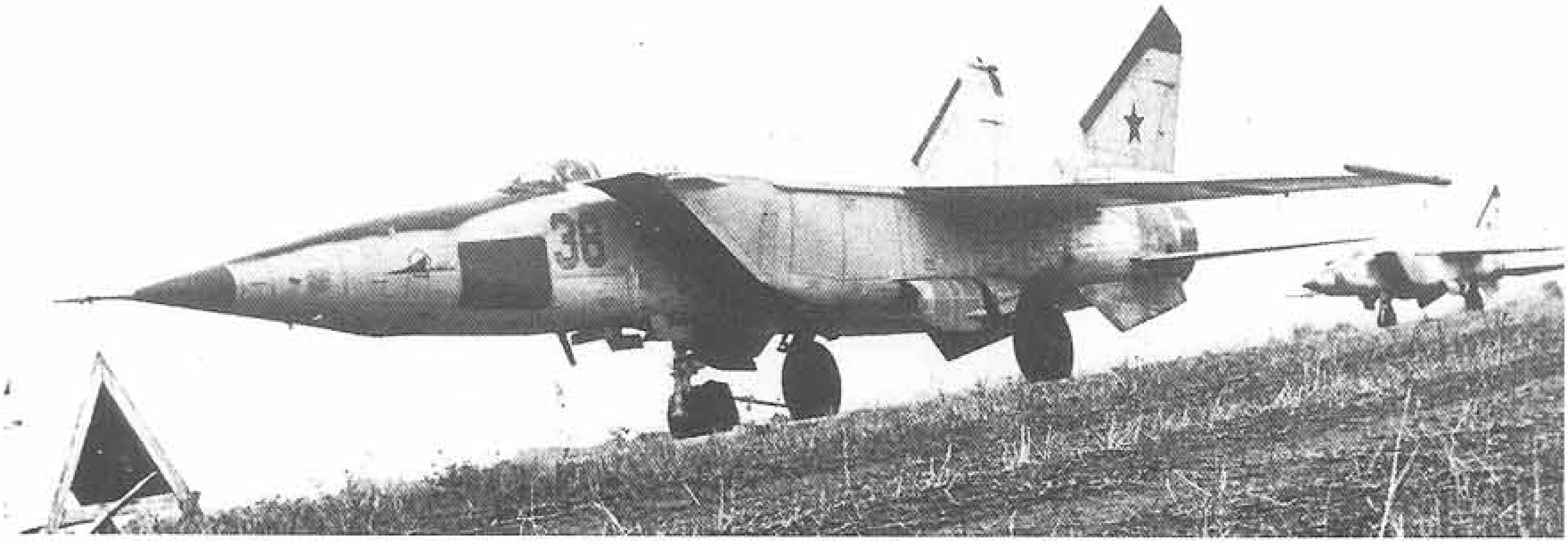
The MiG-25RBK was tested successfully, and was produced at Gor'kiy in 1971–80. Series aircraft had the upgraded *Kub*-3M (*Izdeliye* K-3M), an SPS-143 (*Izdeliye* 143) ECM suite, and the RB's ability to carry bombs.

MiG-25RBS, 02S

Almost in parallel with the MiG-25RBK a second dual-role version entered production in 1971. The 'S' suffix indicated that this aircraft carried the *Sablya* (sabre) monobloc SLAR (side-looking airborne radar), *Izdeliye* 122. The Moscow Instrument Research Institute had suggested developing a SLAR for the MiG-25 in 1963, but it was 1965 before the VVS completed a specific operational requirement for such a version.

It took almost seven years for *Sablya* to be designed and debugged, but in 1970 it was successfully tested on a MiG-25RB. The new version could be identified by the large dielectric rectangles on each side immediately ahead of Frame 1 at the windscreen, and the differently shaped skin panels. The MiG-25RBS had an SPS-142 (*Izdeliye* 142) ECM pack, and could carry the same bombs as the strike version. The radar picture was 'developed' in a special ground vehicle, and gave excellent picture quality, but the SLAR proved extremely troublesome, and was also unable to function below 17,000m (55,774ft).

A single directive of the Council of Ministers covered the Service use from 1972 of the MiG-25RB, RBK and RBS. Gor'kiy produced the



MiG-25RBS. (Yefim Gordon archive)

MiG-25RBS until 1977. Some RBS aircraft were later fitted with new Elint equipment.

MiG-25RBV, 02B

From 1978 many MiG-25RB aircraft were upgraded by replacing the SRS-4A and SRS-4B Sigint packs by the more modern SRS-9 *Virazh* (turn), *Izdeliye* 31. Later these aircraft were further updated by replacing the *Siren'* ECM installation with the SPS-151 *Lyutik* (buttercup). The updated aircraft were designated V for *Virazh*, the 02B factory code remaining unchanged. Confusingly, from 1976 the RBV designation was also applied to aircraft not updated and still fitted with SRS-4; the *Izdeliye* number was not changed. One example, callsign '68', was fitted with a retractable inflight-refuelling probe extended above the nose behind the *Kub*. From 1981 these aircraft were fitted with the more modern *Shar*-25 installation.

MiG-25RBN, 02N

To meet VVS demands Mikoyan made provision for high-altitude photography at night. The nose was fitted with two NAFA-MK-75 night cameras produced by Kazan Optical and Mechanical Plant, with optical axes tilted slightly aft. Underfuselage racks carried four to ten FotAB-100 or FotAB-140 flare bombs. These were released over the target by the *Peleng* system; the flash triggered the camera shutters and lasted long enough for two exposures.

During trials the procedure was changed: the shutters were left open, and closed after the flash. Eventually it was decided the complicated mission yielded only sixteen pictures of indifferent quality, and was impossible in overcast conditions. Over friendly territory the FotAB caused panic, and posed a hazard from splinters. The RBN (*nochnoy*, night) version was therefore not submitted for State acceptance testing.

Dimensions as other R versions.

Weight empty 19,980kg (44,048lb); fuel 15,000kg (33,069lb); takeoff weight (four FotAB) 35,740kg (78,792lb), (eight FotAB) 36,240kg (80,291lb).

Maximum cruising speed (FotAB) 2,390km/h (1,485mph), (after release) 2,500km/h (1,553mph); cruise altitude 20,700m (67,913ft); combat radius (four FotAB) 530km (329 miles), (eight FotAB) 505km (314 miles); takeoff (eight FotAB) 23sec, 355km/h (221mph), 1,200m (3,937ft); landing speed 290km/h (180mph); landing run 800m (2,625ft).

MiG-25RBT, 02T

In 1978 the Gor'kiy factory began production of this version, which differed from the RBV in having the *Virazh* Sigint pack replaced by the *Tangazh* (pitch angle). This Elint receiver could detect, locate and analyse radars over a wider range of wavebands: PD radars (0.8–300cm) and CW (2.8–3.6cm).

MiG-25RBSh, 02Sh

An upgrade programme for the MiG-25RBS was launched in 1981. The troublesome *Sablya* was replaced by the new-technology *Shompol* (ramrod). This solid-state installation proved vastly better, with 2–3 times better picture resolution and the ability to be used at any height from 300 to 23,000m (984–75,459ft). It also introduced an MTS (moving-target selection) mode and a combined mapping/MTS mode.

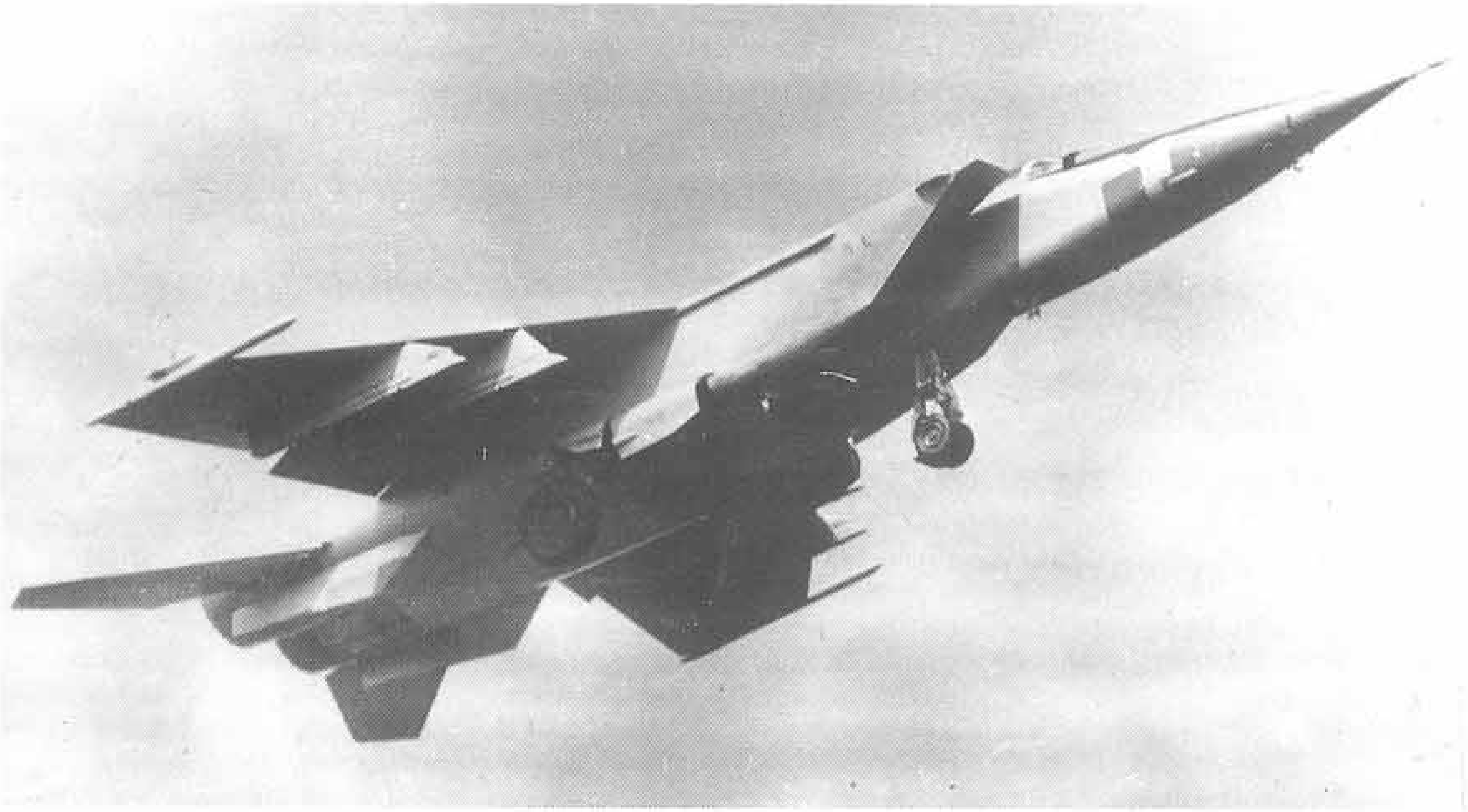
MiG-25RBF, 02F

In 1981 the MiG-25RBK was also given a midlife update. The old-technology *Kub*-3M Sigint suite was replaced by the solid-state *Shar*-25 (ball, balloon). As this was more compact the upgraded aircraft could also carry panoramic cameras, a complete ECM installation and chaff/flare dispensers. The new Sigint suite was faster in operation, and could work in a jumbled electronic environment, picking out assorted transmitters of many kinds. It could detect, analyse and locate modern radars with complex emission spectra, and relay data to ground centres.

The suffix Sh having already been used, the letter F was chosen for this version. The MiG-25RBF could be identified by its small dielectric windows low on both sides of the nose. The RBSh and RBF upgrades were done at VVS repair shops as aircraft came in for major overhaul.

MiG-25RR

This version was developed to replace the Yak-25RR and Yak-25RRV in the Rint (radiation intelligence) mission. This involved upper-atmosphere sampling, to detect the presence of radioactivity. All the small number put into service were MiG-25R and RB aircraft, modified by the Mikoyan bureau under a *Vysota* (altitude) programme. The main modification was to remove other mission equipment and add filter canisters under the wings. Compared with the aircraft it replaced,



MiG-25BM prototype. (photograph by Viktor Drushlyakov)

the MiG-25RR could fly at higher altitude, and it could fly three times as fast, decreasing pilot exposure.

MiG-25R export

In parallel with the export version of the MiG-25PD, an export version of the MiG-25R was developed for suitable customers. Most were equipped only for various reconnaissance missions, but some, certainly including those of Algeria and Iraq, were to RB standard. Customers comprised Algeria (10), India (6), Iraq (8), Libya (5) and Syria (8). Four were supplied to Bulgaria, but were soon exchanged for MiG-23BN tactical aircraft. Several Iraqi aircraft were lost during the war with Iran due to accidents and 'bad tactical planning'.

Ye-155B project

Inspired by the success of the MiG-25RB, the OKB proposed this pure bomber version. It was to have a navigator/bomb-aimer able to use an *Ivolga* (golden oriole) electro-optical sight capable of detecting small targets by day or night, as well as a radar for bombing ships and targets with large radar cross-section. The project never even reached the drawing board.

Ye-155K project

This project from the late 1970s was for a defence-suppression aircraft. Even the MiG-25 was expected to be vulnerable to the most powerful SAMs, and after the development of the Kh-58 ARM (antiradar missile) it appeared possible to destroy enemy missile guidance radars before the SAM could be fired. After careful study this version of the MiG-25RB was proposed, retaining reconnaissance and bombing capability whilst being fitted with two *Landysh* (lily of the valley) ECM installations and two Kh-58U missiles. Suffix 'K' stood for *kompleks*. The project failed to receive funding, but did lead to the MiG-25BM.

MiG-25B project

This reconnaissance/strike/defence-suppression proposal dated from 1977. It was to carry the *Espadron* (a heavy two-handed sword) complex, comprising a *Shompol* SLAR, a new Sigint pack, a thermal imaging system, a data-link system and Kh-58U ARMs. At the same time consideration was given to fitting ARMs to Photint aircraft.

MiG-25BM, 02M

Having failed with the Ye-155K and MiG-25B, the Mikoyan project staff reached agreement with the VVS that the defence-suppression mission should not be met by adding to an RB aircraft but should be a specialized variant in its own right. The objective was to develop a version with a range of powerful ECM sets with a wide frequency spectrum, carrying four Kh-58 missiles. Such an aircraft could not only pierce defences for MiG-25RB aircraft but could also search for and destroy hostile radars over a specified section of front line. It took thirteen years from the proposal for this version to enter service. One reason for the delay was the need for extensive modification to the missile. Following repeated failures, it was given a new motor. To enable it to be carried by other types of aircraft it received a different tail, hence the designation Kh-58U (*unifitsirovannyi*, standardized). Special equipment had to be developed to enable a 'wolf pack' to cover territory as large as a small country. Its functions included threat selection, prioritization, destruction of targets at known coordinates, definition of missile launch zones and missile performance monitoring all along the trajectory. Called *Yaguar* (jaguar), this system took time to perfect.

A further Tupolev Tu-104 was converted by LII-MAP to test equipment for EM (electromagnetic) interference. One programme solved the problem of targeting errors, especially with long-wave radars, when the enemy was using decoy transmitters located close at hand. The software for the *Peleng* navigation complex had to be extended, updated and debugged. Prolonged testing was necessary for launching the missiles from the AKU-58 ejector rack, which incorporated an alcohol/water missile cooling system.

The MiG-25BM prototype was completed in 1976, before most of the development had been done. Flight tests showed virtually no deterioration in performance, despite a 200mm (7.9in) plug lengthening the nose to make room for the extensive ECM and missile-guidance equipment. The missiles were carried on four wing pylons, the wing having attachments similar to those of the P versions, fitted with AKU-58 interfaces which could be exchanged for racks for bombs. Extensive trials were done, mainly against real radars which tried all known ECCM tricks.

Fewer than one hundred MiG-25BM aircraft were built, in 1982–85. To simplify conversion training they were delivered to independent reconnaissance units already flying the RB. The 'Wild Weasel' version, a name used in the VVS, could be identified by its nose painted dark grey or olive drab, with distinctive dielectric panels and radar-homing antenna blisters, and by the pylons with ECM antennas. Pilot and ground-crew training took a long time, but the system was declared operational in 1988. The ASCC name was 'Foxbat-F'.

The Gor'kiy factory completed production in 1985, the final new-build version being the MiG-25BM. Excluding prototypes, the total number of MiG-25s built was 1,186. The MiG-25 earned its creators numerous State prizes. The most valued were the Lenin Prizes won by R A Belyakov, general designer; Nikolai Matyuk, a chief designer; I Silayev, director of the Gor'kiy factory (later Minister of Aircraft Production); F Shukhov, chief designer of the engine; F Volkov, chief designer of the radar; and A Minayev, deputy chief designer and leader of the team in Egypt.

MiG-25PDZ

As already mentioned, a number of MiG-25s were fitted with inflight-refuelling probes. The most advanced was this converted MiG-25PD (Z for *zapravka*, refuelling), code 'Blue 45'. The L-shaped probe was located ahead of the windscreen, offset slightly to starboard, in an extra section of fuselage housing the retracted probe and associated equipment. After a few tests the probe was shortened, and then a major modification was needed to move the probe to the left side for commonality with later MiG-29 and Su-27 fighters. To simplify formating on the tanker a microcontrol system was tested successfully in which engine thrust was slightly vectored by moving petals of the nozzles. Eventually the system was cleared for use, but the very few Ilyushin Il-78 tankers were tasked mainly with refuelling A-50 surveillance aircraft. Accordingly, it was decided not to modify the MiG-25s, but to fit flight refuelling to the MiG-31.

MiG-25RBVDZ and MiG-25RBShDZ

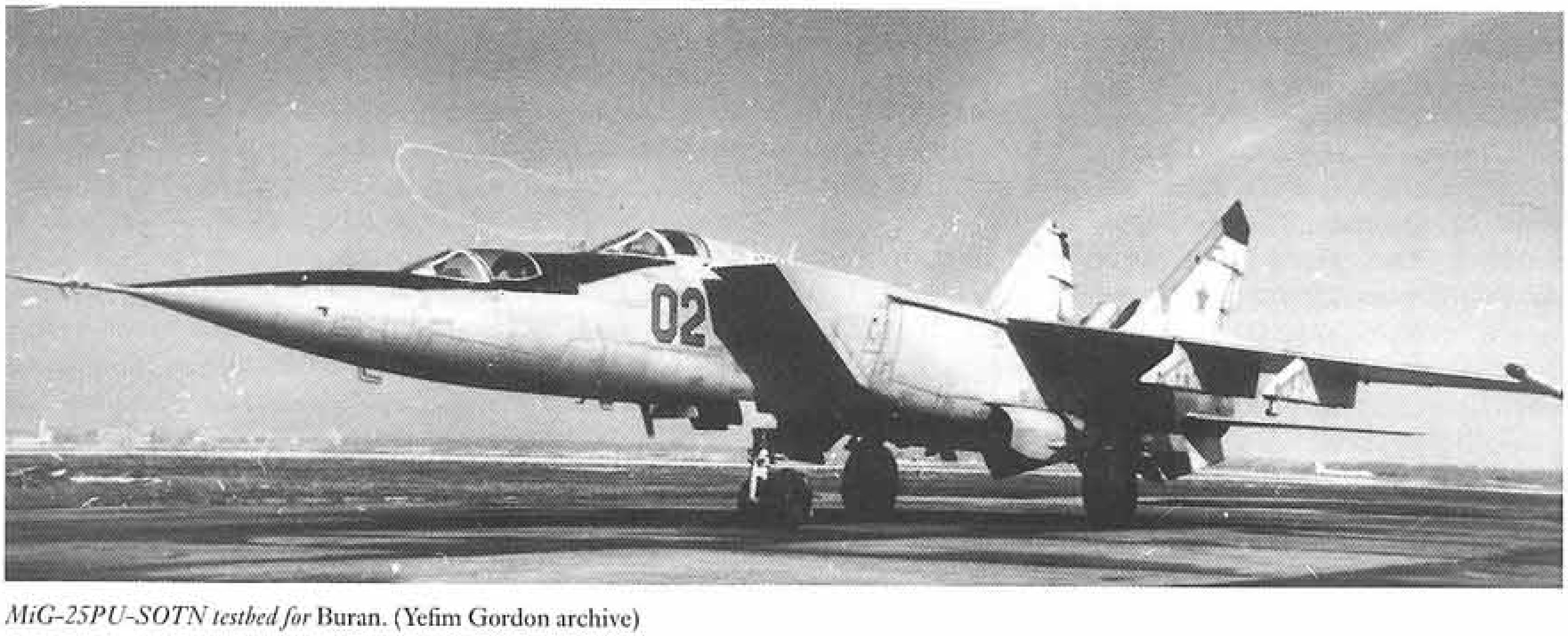
To test flight refuelling on reconnaissance/strike versions, retractable probes were fitted to a MiG-25RBV ('Red 68') and a MiG-25RBSh (no code). Designation DZ signified *dorabotannyi dlya zapravki*, upgraded for refuelling. In these aircraft presence of the mission equipment dictated that the extra section incorporating the probe should be much further forwards, and as before it was offset to the right. Successful tests took place with an Il-78 tanker, and fuel could also be taken from Su-24M tactical bombers fitted with the UPAZ-A 'buddy pack'. In the end it was decided that, as the Su-24MR could fly the mission and was already fitted with a probe, the proposed MiG-25RB upgrade was abandoned.

MiG-25RU/K-36RB testbed

This was one of three MiG-25 aircraft used to support the *Buran* (snowstorm) spacecraft programme. Initially coded 46, and later 'Blue 01', it had a rear cockpit modified to fire the specially developed Zvezda K-36RB seat. The normal canopy was replaced by a cutaway metal fairing, and seat ejection was recorded by a camera in a dorsal fairing above the nose. After the *Buran* programme this aircraft was used to test other types of seat.

MiG-25PU-SOTN

This MiG-25 trainer, call sign 'Blue 02', was converted into the *samolyot optiko-televizionnovo nablyudeniya*, optical TV surveillance aircraft. Its duties included collaboration with three Tupolev Tu-154LL control-system testbeds and approach trainers in research for the ideal *Buran* approach trajectory, checking monitoring of the *Buran* flight-control system, training *Buran* pilots and navigator/system operators, and acting as chase plane. Equipment included a Sony DXM-3P



MiG-25PU-SOTN testbed for Buran. (Yefim Gordon archive)

MiG-25RB testbed for Buran *programme.* (Yefim Gordon archive)

video camera, 3800PS video recorder, DX-50 monitor, KL-108 transmitter and MB-10 antenna, together with a KRL-78 radio command link integrated with the SAU-155 flight controls, a B-218 data link and test instrumentation. The SOTN would first rendezvous at about 18,000m (59,055ft) with the target aircraft. Until the *Buran* flew, targets included a modified MiG-25RB ('Red 02'), a MiG-31 ('Red 97') and the 'BTS-002' (SSSR-3501002), which was a *Buran* fitted with four AL-31 engines and a longer nose gear for taking off under its own power. It would then throttle back, lower its landing gear and formate down the steep glide path whilst recording. Stage A comprised fifteen flights to check out the system; some signals were corrupted by radar altimeters of aircraft in the vicinity. Stage B, in September–October 1986, established optimum target distance at 10m (33ft), and a Betacam camera was used as an added monitor in the rear cockpit. Stage C, held at Eupatoria, Crimea, on 11–16 October 1986, included ten flights with the total system. On the *Buran*'s first space mission the SOTN, flown by Magomed Tolboyev, intercepted the vehicle after re-entry and videotaped its entire approach and landing.

MiG-25RB testbed for *Buran* programme

This aircraft, code 'Red 02', was mentioned earlier as one of the test vehicles in support of the *Buran* programme. It could be identified by extra dielectric panels on the sides of the inlet ducts and test-instrumentation carried in heat-resistant containers on the wing hardpoints.

Ye-155M, MiG-25M

These designations both applied to two quite different aircraft used to develop a more powerful engine. The need for this stemmed from the 1972 directive ordering Service entry of the RB, RBK and RBS, because this called for an increase in ceiling, maximum speed and range at low and medium altitudes. From the outset the aircraft had had the potential to go faster, at the expense of reduced lateral stability and airframe life, and Tumanskiy's engine designers Shukhov and Rotmistrov were developing the more powerful R-15BF2-300. This engine was installationally interchangeable, but was rated at 10,000kg (22,046lb) dry and from 13,230–14,500kg (29,167–31,967lb) with afterburner. Mikoyan decided to test the engine on a structurally standard MiG-25, and then fly it in a second aircraft with light-alloy or plastics parts replaced by steel or titanium honeycomb. The VVS and MAP agreed and gave the go-ahead in September 1964, but bench testing the engine took longer than expected.

The engine testbed was first flown as a MiG-25PD (F/n 84019175) on 12 June 1973, with regular engines. It was re-engined with R-15BF2-300 engines, received a new F/n (841710) and code 'Blue 710', and began flight tests on 30 August 1973. The structurally rebuilt aircraft was a MiG-25RB which received the new F/n 02-601, code 'Blue 601'. Both aircraft had a service ceiling just above 24,200m (79,396ft), and '601' had a supersonic range of 1,920km (1,193 miles) clean or 2,530km (1,572 miles) with a tank. On 17 May 1975 Fedotov and Ostapenko used '601' to set new climb records, to 25,000, 30,000 and 35,000m (82,021, 98,425 and 114,829ft) in 2min 23.2sec, 3min 9.85sec and 4min 11.7sec respectively. With further modifications Fedotov used '601' to break his own height records, reaching 37,800m (124,015ft) with 2,000kg payload on 22 June 1977. These records were reported to the FAI as having been set by the 'Ye-266M'. Soon afterwards a pressure-relief valve failed, causing a fuselage tank to explode. Though a large piece of upper fuselage skin came off, Aviard Fastovets landed safely. In 1975 'Blue 710' was fitted with an R-type wing and new tailerons from another development aircraft, 'Blue 502'. It was not withdrawn until 1977, by which time attention was focused on the MiG-31. It is displayed at the Moscow Khodynka museum.

MiG-25/D-30F testbed, 99

Despite the above efforts to increase speed and height, the MiG-25P was in practice deficient only in range. Accordingly, two aircraft were experimentally fitted with the new engine developed by the P A Solovyov KB for the MiG-31. Designated PS-30F, or D-30F, this was a turbofan with a maximum thrust of 15,500kg (34,171lb). This was unrelated to the R-15B, and required major modifications to the MiG-25 airframe. After being flight-tested under a Tu-16LL, two of these engines were installed in a MiG-25P, given F/n 99 and code 'Blue 991'. Later another pair were installed in a MiG-25R, coded 'Blue 992'. Conversion was a much bigger job than with the Ye-155M, but due largely to lead engineer M Proshin the Gor'kiy factory solved the problems. It was hoped that the re-engined aircraft could go into production to bridge the gap until the MiG-31 could take over. Though internal fuel was unchanged at 19,700 litres (4,333gal) a subsonic range of 3,000km (1,864 miles) was soon recorded. Normal takeoff weight was 37,750kg (83,223lb), rising to 42,520kg (93,739lb) with drop tank, when transonic range was 3,310km (2,057 miles). Service ceiling was 21,900m (71,850ft). However, once the MiG-25MP, the prototype MiG-31, entered flight tests in autumn 1975 these aircraft were used merely as engine testbeds.

MiG-25PD, 84-20

In 1992 one of the MiG-25PD interceptors, coded *Izdeliye* 84-20, used by the Mikoyan OKB at Zhukovskiy had one of its engines replaced by a secret fighter powerplant (almost certainly the Saturn AL-41). Special precautions had to be taken, since the new engine was much more powerful than its partner and had a totally different all-electronic control system for both the engine and its modified inlet. Stage A of the test programme, including supersonic flight, was completed without major difficulty. Aircraft 84-20 was post-Soviet Russia's first supersonic engine testbed.

MiG-31

In 1968 the Council of Ministers issued a directive ordering the Mikoyan OKB to design and build three versions – interceptor, strike and reconnaissance – of an aircraft designated Ye-155M. This was a project unrelated to the MiG-25M described previously, though initially the Ye-155M was envisaged merely as an upgraded MiG-25. After 1970 the demands were greater, and focused on the need for a better interceptor.

The vast extent of the northern and eastern boundary of the Soviet Union had made it impossible to provide adequate air defence. Airfields, radars and airspace-control systems were far too thinly spread to provide any defence against even bombers, let alone bombers carrying small hypersonic missiles. The last straw was the emergence of the USAF's AGM-69A SRAM, carried by the Boeing B-52 and General Dynamics FB-111, a nuclear missile which could fly at high supersonic speed at low level.

Mikoyan proposed to develop the MiG-25PD into a new aircraft able to cruise at 3,000km/h (1,865mph) for exceptional distances and destroy multiple targets in a single sortie, operating autonomously without any ground guidance. Its crew was to comprise a pilot and WSO (weapon-systems officer, serving as tactical director). This proposal was supported by the government and by the IA-PVO. The OKB accordingly studied three different configurations of the Ye-155MP (*modifitsirovannyi perekhvatchik*, modified interceptor). For better fuel economy all were intended to be powered by the D-30F engine already mentioned (tested in MiG-25s 'Blue 991' and '992'). Despite the increased wing loading, all were to be stressed to 5g for higher speed at low level and enhanced manoeuvre capability. Armament would have comprised three or four long-range missiles recessed under the fuselage and short-range missiles on glove pylons.

The three configurations differed from the MiG-25 mainly in the type of wing:

Version A was to have wings derived from those of the MiG-25PD but with three spars and LERX (leading-edge root extensions).

Version B was to have variable-sweep wings derived from those of the MiG-23, one advantage of which was increased loiter time. It would also have had a tail resembling the MiG-23, but with two folding ventral fins, and the main landing-gear units would have been four-wheel bogies.

Version C would have been aerodynamically related to the Tupolev Tu-144, with a large-area ogival delta wing with elevons in place of a horizontal tail.

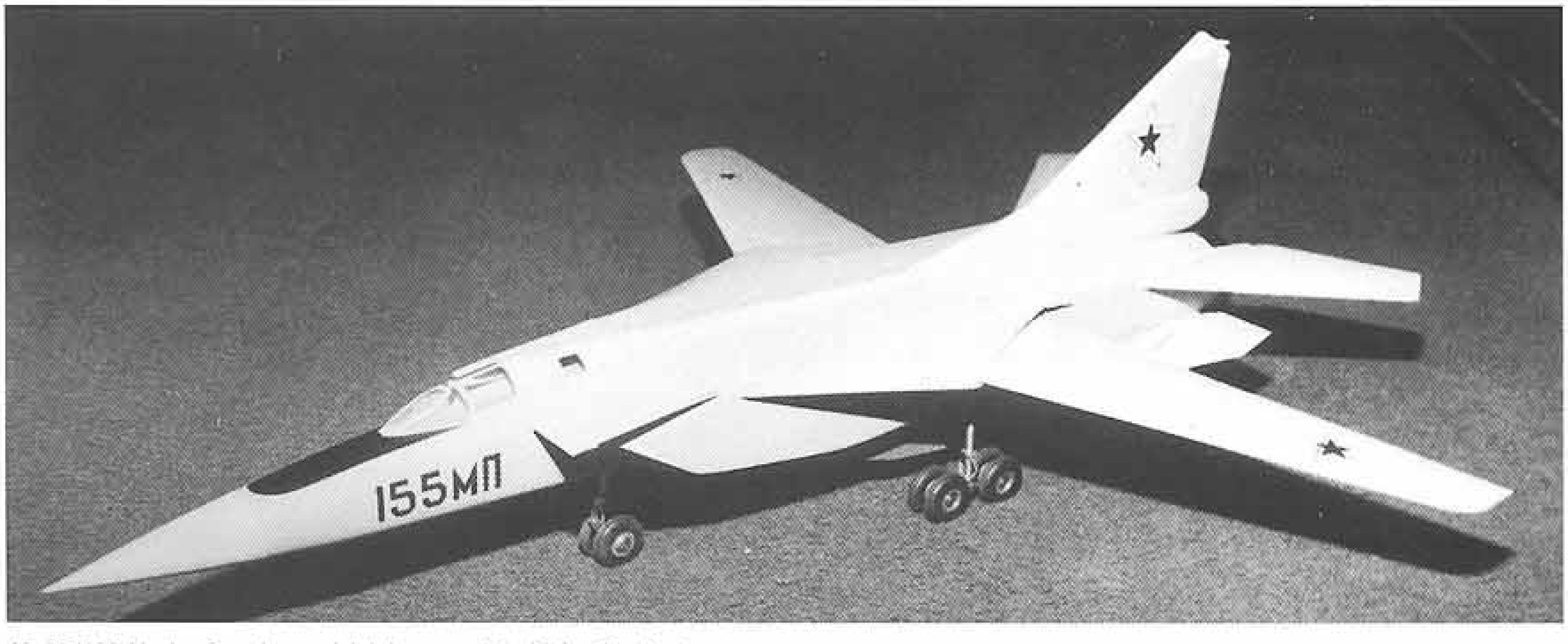
***Izdeliye* 518-31** This might have been the designation for Version B.

***Izdeliye* 518-55** This project came between Version A above and the eventual MiG-31. It had extra-large LERXs and a unique kinked trailing edge, and the main landing-gear units had two wheels in line. Four R-33 missiles would have been recessed under the fuselage.

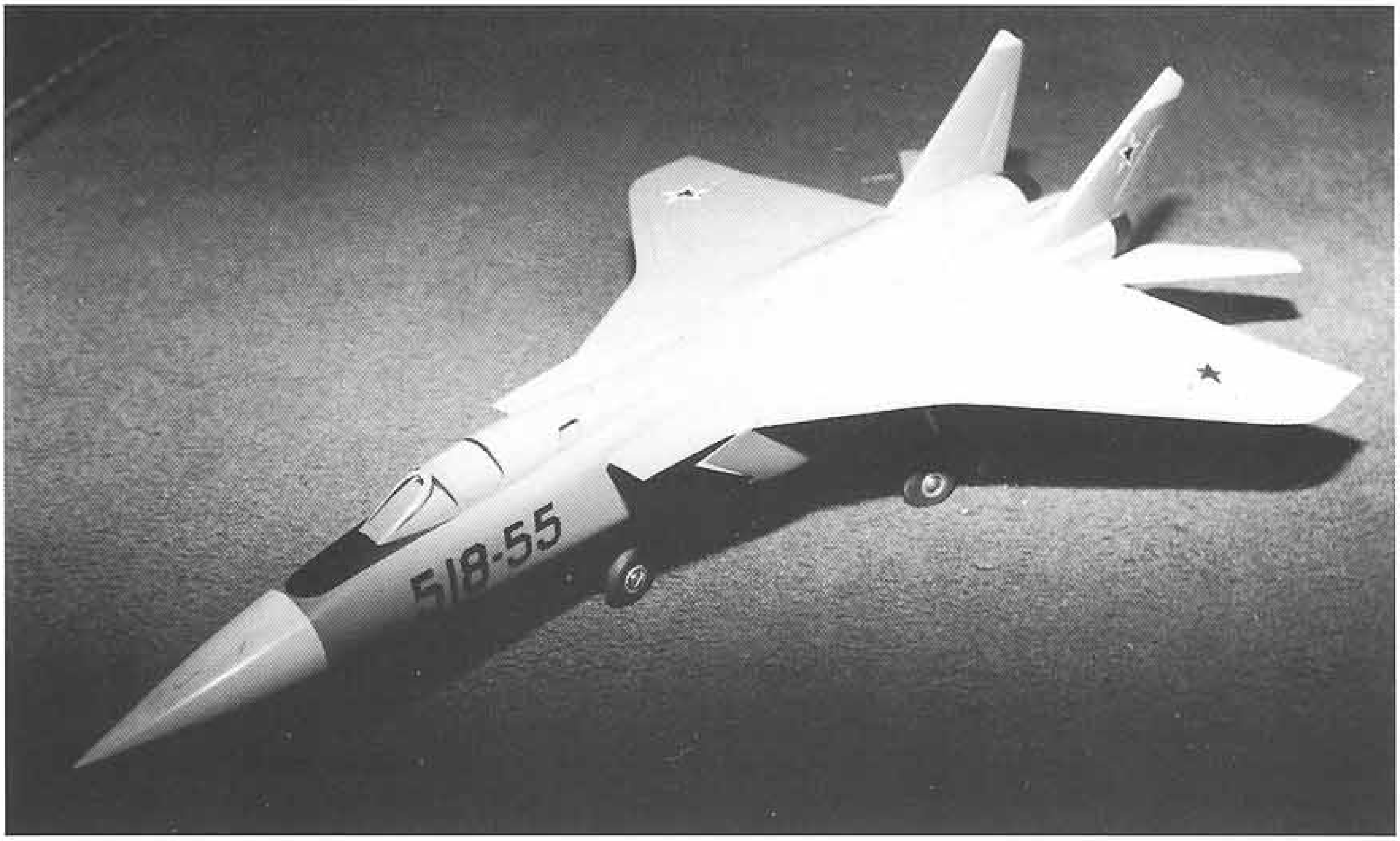
Ye-158 This project for a tailless two-seat interceptor with an ogival wing may have been Version C.

Ye-155MF project

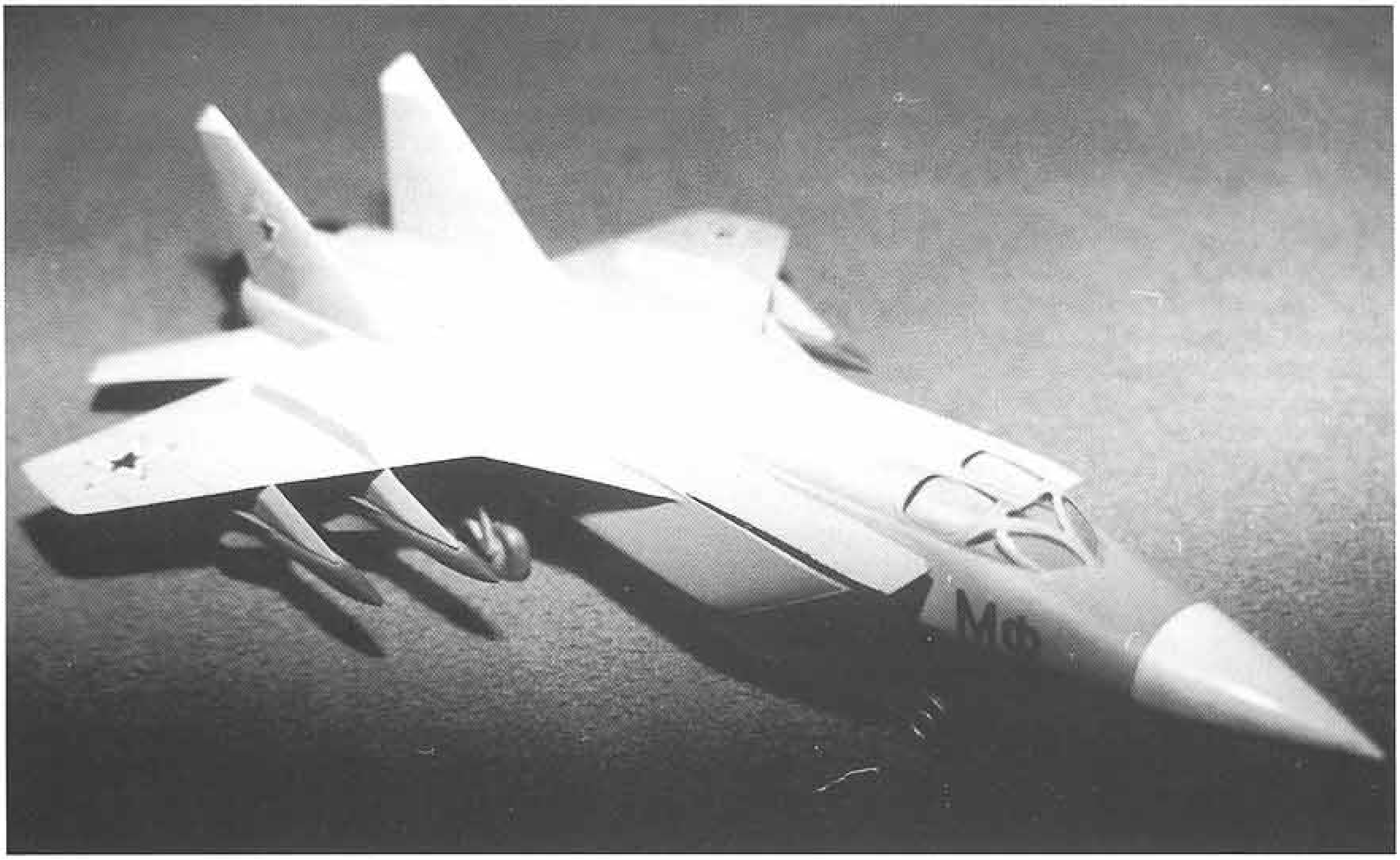
As work started on the Ye-155MP (*see* next), the Mikoyan preliminary designers decided to study an MF (F



Ye-155MP Version B project model. (photograph by Yefim Gordon)



518-55 project model. (photograph by Yefim Gordon)



Ye-155MF project model. (photograph by Yefim Gordon)

for *frontovoy*, tactical) version. This would have been designed to penetrate enemy airspace at high supersonic speed, taking out defending radars and hitting high-priority targets with precision missiles and bombs. Differences from the MP version would have included the WSO sitting beside the pilot for better view ahead, and four large wing pylons. A typical load would have been four Kh-58 antiradar missiles and twelve FAB-250 bombs carried in fuselage bays. This proposal was rejected in favour of the Su-24.

Ye-155MP, MiG-25MP, 83

After assessing the above configurations, the preliminary design department began to issue drawings for this prototype in 1972. Under the supervision of R A Belyakov, it was designed around the D-30F6 engine, which was being created in parallel specifically for this aircraft, and the SBI-16 *Zaslon* (meaning a barrier or impenetrable force) phased-array radar. From the outset it was agreed that the weapon-systems officer should sit behind the pilot, and be provided with a duplicate set of flight controls (with a retractable control column) and forward-facing periscope, to enable him in emergency to take over from the pilot and also to render a separate training version unnecessary.

Development of the Ye-155MP to clearance for service as the MiG-31 took nine years. Though the MiG-31 looks very much like a MiG-25P the two aircraft are totally different in structure, aerodynamics, propulsion, systems and, above all, in avionics/weapons. The basic requirement was 'to intercept and destroy manoeuvrable and nonmanoeuvrable targets flying at any speed and height in the front or rear hemisphere, day or night, VFR or IFR, in an active or passive jamming environment while itself flying at high supersonic speeds'. It is described as a fourth-generation interceptor. A particular feature was to enhance the lift from the body and intakes until at high angles of attack this provides 50 per cent of the total. A detailed description of the MiG-31 is provided later. What follows is an account of how this aircraft was developed.

To overcome the lack of torsional stiffness which had troubled the MiG-25 the wing was given a third spar. To eliminate tip stall at high angles of attack the outer wings were slightly cambered. To enhance manoeuvrability at high AOA the body lift was further augmented by the LERX, with a leading-edge angle of 70°. To improve field length and lift in the loiter mode the leading edges comprised four sections of droop flap, while in contrast to the MiG-25 almost the entire trailing edge was composed of flaps and flaperons.

Designed at the OKB, the main landing gear was a significant advance over the MiG-25. By adopting two small wheels in tandem the weight was considerably reduced, and the footprint enlarged to spread the greater weight of the MiG-31 over a larger area. The retracted landing gear was arranged to rotate during retraction to fit into a smaller fuselage bay, and the unique arrangement of making the front axles face inwards and the rear axles face outwards made the tyres form separate furrows in snow or slush, enabling this very heavy aircraft to operate from soft airstrips in a way impossible with a MiG-25. The units retracted forwards and the large front doors formed airbrakes which were normally closed except when the landing gear was actually cycling. They were stressed for use without restriction except at supersonic speed at low level.

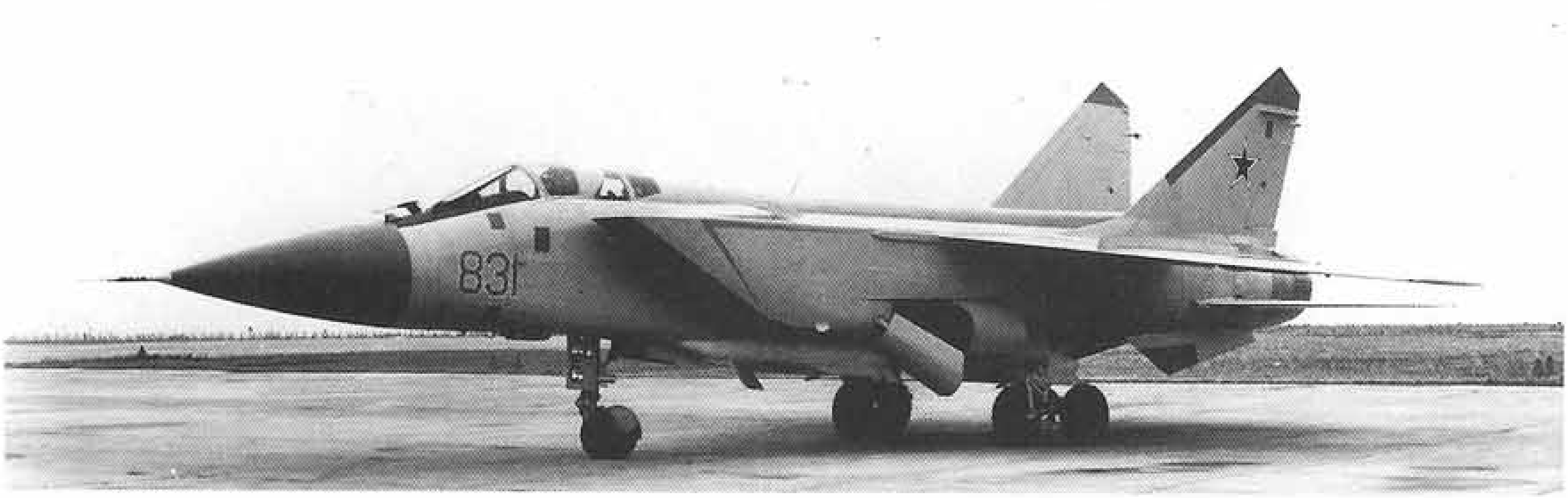
Predictably, the biggest development problems involved the radar and engines. The two prototypes, designated Ye-155MP or MiG-25MP or *Izdeliye* 83, were built at the OKB's experimental factory in Moscow, but were delayed by organizational bureaucracy. In 1975 a meeting of PVO commanders noted that, though the first prototype had yet to fly, it had been the subject of thirty-three government directives.

At last, the first aircraft, callsign 'Blue 831' (*Izdeliye* 83 No. 1) was completed in mid-1975, but without the gun or some avionics and with the radar replaced by test instrumentation. OKB chief test pilot Aleksandr Fedotov was appointed to fly it, supported by S G Polyakov as leading engineer and V N Keechev as '831's personal technician. Fedotov made the first flight at Zhukovskiy on 16 September 1975. He was soon joined by Pyotr Ostapenko, Boris Orlov, Aviard Fastovets, Valeriy Menitskiy and Toktar Aubakirov, and navigators Valeriy Zaitsev and Leonid Popov.

The second prototype, 'Blue 832', had a complete fit of avionics and weapons. It was first flown by P Osipenko (not to be confused with Ostapenko) at Zhukovskiy in May 1976. Later it was flown to Akhtubinsk for NII-VVS testing, with leading engineers Leonid Sveederskiy and Edward Kostrubskiy. Despite many problems during four years of testing the new interceptor was so far in advance in radius of action and weapons/avionics system that the Gor'kiy factory was instructed to prepare for production two years before testing was completed.

MiG-31, 01

The first series batch comprised two aircraft, F/n 0101, callsign 'Blue 011', completed about May 1977, and F/n 0102, 'Blue 012', completed in late 1977. The first lacked radar and was used for aerodynamic, static and fatigue tests; it was the first to conform aerodynamically to production standard. The second was used for performance testing. Block 2 comprised three aircraft,



Ye-155MP/1, MiG-25MP 'Blue 831'. (Yefim Gordon archive)

MiG-31 series aircraft. (photograph by Victor Drushlyakov)

'Blue 201' (F/n 0201), '202' and '203'. Block 3 comprised four aircraft. All aircraft in the first three blocks were used for the trials programme.

The first aircraft suffered two major problems. Orlov suffered engine failure but made a normal landing, whereupon it was found that the failed engine had exploded, knocking out one hydraulic system and other items. Later, on a test from Akhtubinsk, Ostapenko and Popov ejected, and 'Blue 011' fireballed a moment later. Stage A, performed mainly by the OKB, was completed in December 1978. Stage B began at the NII-VVS in spring 1979, head of the commission being Marshal Ye Savitskiy, deputy C-in-C of the PVO.

Additional OKB pilots joined the test programme, among them Anatoliy Kvotchur, Roman Taskayev and Aleksandr Krutov. Many sorties were a severe test of man and machine; for example on maximum speed/ceiling tests Kvotchur had to spend five hours strapped in and wearing a pressure suit. Problems continued. After a test by Krutov to 15,000m (49,213ft), Mach 2.6 and 5g, numerous cracks were found in the fuselage. On a test of structural strength both afterburners disintegrated at supersonic speed at low level. First flown by factory pilot Khirodinov at Gor'kiy on 27 April 1979, 'Blue 305' (F/n 69700104801, or 0305) had strengthened engine-bay bulkheads, inlets and wing box, a new brake-chute container and a new fairing between the engine nozzles. With dummy R-33 missiles it was subjected to maximum speed/g loads. It eventually crashed, Pyotr Gladkov and his WSO ejecting.

In early 1980 the Act of Acceptance for Stage B was signed, enabling some aircraft to be delivered to a regular PVO unit for Service trials. The MiG-31 was officially added to the inventory in May 1981, though the final Act of Acceptance was not signed until December. Full deliveries to units in the Moscow PVO area, the Arctic and Far East, began in 1982.

OKB testing continued, and so did problems. On the eighth aircraft, 'Blue 303', the main 80mm fuel pipe

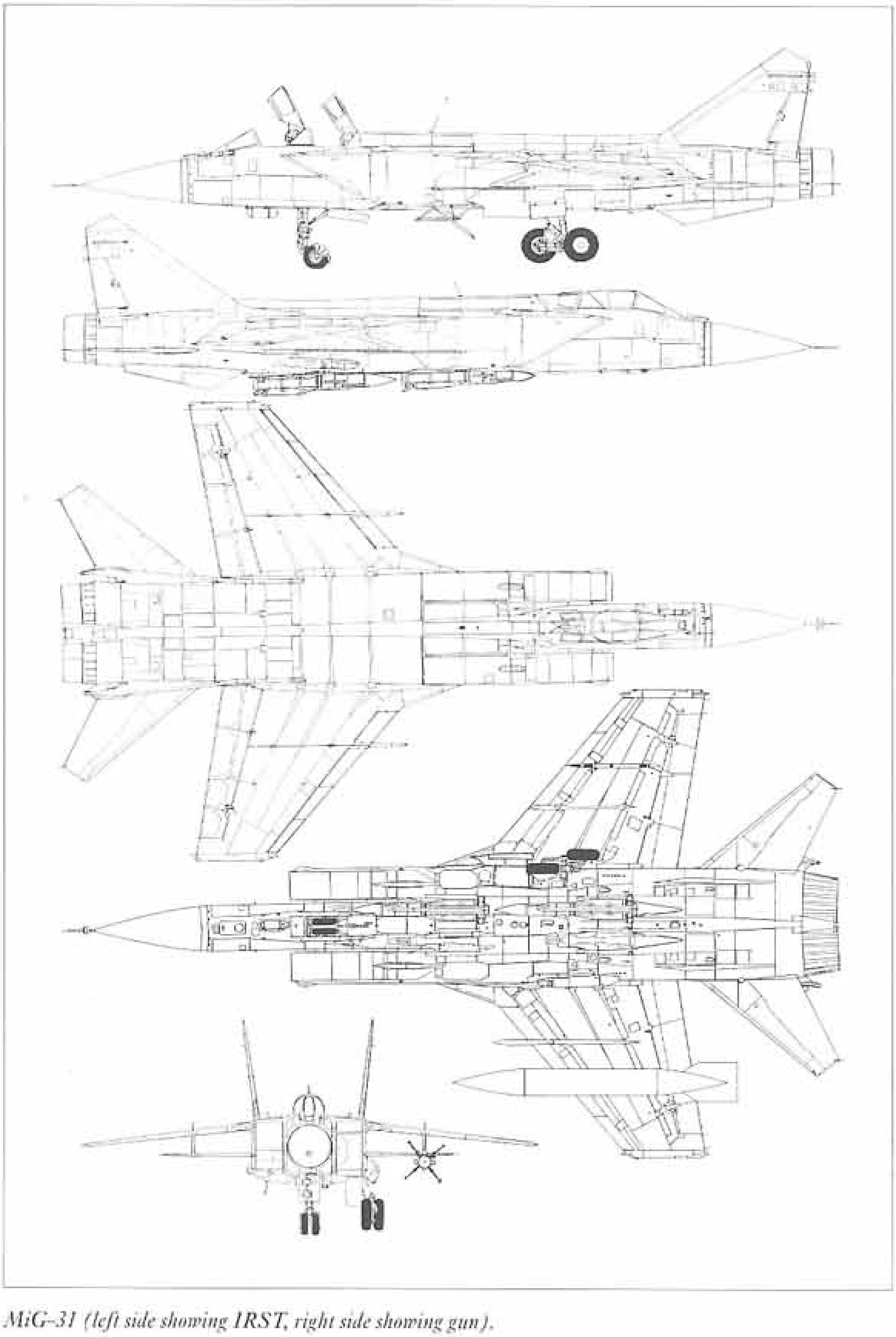
MiG-31 'Blue 202'. (Yefim Gordon archive)

MiG-31 'Blue 202'. (OKB)

to one engine fractured (at a defective nipple used for ground pressure testing), pumping fuel into the engine bay. Thanks to the modest casing temperature of the bypass-type engine it did not catch fire, but fuel was soon exhausted, stopping both engines. Menitskiy ordered WSO Viktor Ryndin to eject, but got the reply 'not without you', and they walked away from the off-airfield landing.

Fedotov had authority to reject anything he did not like, and this accident led to a redesign of the fuel system, tested on 'Blue 201'. This very 'tired' aircraft had a suspect fuel gauge which on 4 April 1984 led Fedotov to believe he was rapidly losing fuel. He made a sharp manoeuvre to return to the airfield, flicked into a spin and just failed to have sufficient height to recover. Both he and Zaitsev were killed. This led to exploration of spinning and other dangerous situations, flown by Orlov, Fastovets and Menitskiy (who was appointed the new chief test pilot).

Though the airframe was derived from that of the MiG-25, hardly any part is common to both types. A detailed audit of structure soaked at simulated 3,000km/h enabled the materials to be used in different proportions. The percentage of arc-welded steel was reduced to 50 (compared with 80 for a MiG-25), whereas titanium accounts for 16 (up from 8), aluminium alloys for 33 (up from 11) and other materials 1. Again, a high proportion of the joints are made by spot and argon-arc welding.



MiG-31 (left side showing IRST, right side showing gun).

The one-piece wing has a very small leading-edge radius, an aerofoil profile of CAHI P44M at the root (where thickness/chord ratio is 3.7 per cent) and P101M (4.48 per cent) at the broad squared-off tip. Leading-edge sweep is 70°30′ to the end of the LERX and 41°02′ from there to the tip. Aspect ratio is 2.93, taper ratio 3.14, incidence 0° and anhedral –5°. There are three spars, which divide each half-wing into two integral tanks. Basic materials are VNS-2 and VNS-5 high-strength stainless steel, the skins being OT4-1 and VT-20 titanium alloy. The leading-edge flaps can be hinged down hydraulically to –13°. The two inner surfaces on each trailing edge are plain flaps each 2.682m (105.6in) long, able to rotate down to 30°. Outboard are two flaperons each 1.7m (66.9in) long, with limits of ±20°; for landing they can droop 5°, in which case the limits become +15°/–25°. Each wing has a single fence running from the leading edge (between two droop sections) to the leading edge of the flap. Immediately underneath are front and rear attachments for a pylon for a tank or missile. Further out are attachments for a pylon which can have launchers for two short-range missiles. Six fixtures attach the wing centre box to the fuselage.

The fuselage has a length of 20.62m (67ft 7⅞in). Like the MiG-25, it has the form of a slim oval-section forward part merging into a much larger main part with a broad rectangular cross-section of 5.7sq m (61.4sq ft) area, faired at the rear into the two very large engine nozzles. It is made as a single unit, but covered in access doors and panels. There are fifty-seven transverse members, the main load-bearing frames being Nos. 1–6, 6B, 7, 9, 10, 10A and 11–14. Joints are both welded and riveted, materials comprising VNS-2 and -5, VNL-3, VL-1, EI-703 and -878 and SN-3 stainless steels, OT4-1 and VT-20, -21L and -22 titanium alloys and S19 and VAL-10 aluminium alloys.

The forward fuselage is made chiefly of riveted aluminium alloy. Ahead of it, secured by nuts and bolts, is the very large erosion-resistant fibreglass radome, carrying the air-data probe on its tip. Next comes the radar-set bay (Web 1 to Frame 1), the pressurized cockpits (Frames 1–3) and an avionics bay behind the cockpits (Frames 3–4). Each cockpit has an aft-hinged canopy which can be partially opened at taxi speeds up to 30km/h (19mph). The optically flat windscreen is a 36mm (1.4in) three-ply sandwich of silica glass with electric-film anti-icing. Side and canopy glazing is 10mm heat-resistant SO-200 Plexiglas. The seats (described later) run on rails attached to sloping bulkheads at Frames 2 and 3, the space above Frame 2 being a 10mm panel of AO-120 Plexiglas. Bays below and behind the cockpit accommodate the nosewheel unit (Frames 1A–3), avionics and electric system components.

The heavily stressed centre fuselage is entirely of high-strength stainless steel, and incorporates attachments for the wings, air intakes, main landing-gear, engines, fins and missile ejector racks. The engine inlets are larger and more complicated than those of the MiG-25, though they have a broadly similar rectangular cross-section, with sharp edges and outer sides which slope from Frame 2 to Frame 6. The lower lips and upper ramps are variable to adjust throat area and shockwave pattern, the actuators being controlled by the ARV-27 automatic system.

The entire upper portion of the centre fuselage, and space above the inlet ducts, forms seven integral tanks, made entirely of special stainless steels and incorporating Frames 4–6, 6B, 7, 9, 10, 10A, 11 and 12. The sides house quickly accessible components for the hydraulic, air-conditioning and pneumatic systems. The lower part houses fuel-system components and the main landing gear. The area-ruled spine houses the push/pull rods and cables controlling the tail, and terminates in the brake-parachute container. In the top of the rear fuselage between Frames 12–13, 13–14 and 14B–14V are three compartments with ATM-3 thermal insulation housing control, fuel and hydraulic components. The tailcone comprises a centrebody welded from EI-703 and a detachable outer portion. The rear fuselage contains fittings for the afterburners and engine accessories, and Frames 13 and 14 attach the tail.

The twin fins have a leading-edge sweep of 54°, outward cant of 8° and combined area of 15.6sq m (167.9sq ft). They are mainly of riveted aluminium alloy, and the spar box of each fin is sealed to form an integral tank. The removable tips and the leading edge of the starboard fin are of glassfibre and cover antennas. Three hinges on each fin attach the rudder. The tailplanes are again riveted D19 structures, apart from the leading edges which are unpainted titanium. Span is 8.75m (28ft 8½in), combined area 9.82sq m (105.7sq ft), leading-edge sweep 50°22′ and anhedral –1°25′. They can operate differentially to augment lateral control. Unlike the MiG-25, the underside of the rear fuselage is flat, and on each side is a riveted aluminium ventral fin, with a dielectric forward section, canted outwards at 12°.

Each unit of the landing gear has a leg of high-strength steel carrying twin wheels, retracting hydraulically. The steerable nose unit has twin KT-176 wheels with 660 × 200mm tyres and an aft mudguard. The leg carries three landing/taxi lights and retracts to the rear. Each main unit has staggered KT-175 wheels with 950 × 300mm tyres, and retracts forwards, the arms carrying the axles rotating around the leg to stow the wheels inverted in a shallow bay outboard of the inlet duct. Wheelbase is 7.113m (23ft 4in) and track 3.638m (11ft 11¼in). All six wheels have antiskid brakes.

On the Ye-155MP prototypes the forward mainwheel doors opened diagonally from the flanks of the fuselage. On the MiG-31 they are under the inlet ducts and hinge straight down on two arms and serve as airbrakes. They have a combined area of 1.39sq m (14.96sq ft) and open to 39°.

The D-30F6 engines are briefly described in Appendix 1. Unlike the MiG-25 they are changed by withdrawing the complete engine and afterburner to the rear. As already described, fuel is housed in seven tanks in the fuselage, four in the wings and two in the fins, giving a total capacity of 19,940 litres (4,386gal). One 2,500lit (550gal) drop tank can be carried on each inboard wing pylon. Normally the MiG-31 carries 13,700 litres (3,013.6gal) in fuselage Tanks 2–5, the wing tanks and half-filled drop tanks. A coolant tank adjacent to Tank 7 is located between Frames 12–13.

The ejection seat is the Zvezda K-36DM, with the widest operational envelope of any seat in the world in the 1980s. The brake parachute container houses two cruciform canopies, each extracted by a small drag chute of 0.05sq m which in turn pulls out a chute of 1.5sq m. The main canopies have a combined area of 50sq m (538sq ft).

In its armament and avionics the MiG-31 differs totally from all versions of the MiG-25. Despite its basic mission of BVR kill, it was considered desirable to include a gun, and this is a relatively new type, the GSh-6-23M. It is a six-barrel 'Gatling' with a maximum rate of fire of 6,000±500 rounds/min, increased in the -23M to 8,000 rounds/min. This rate, which is significantly higher than that of any gun of similar calibre in the world, is combined with ammunition having double the kinetic energy of Western 20mm projectiles. The magazine capacity is 260 rounds, with linkless feed. The gun is mounted on the right side of the fuselage on Frames 10 and 11 immediately behind the starboard mainwheel bay. Except when firing, the muzzle is faired by a door.

The main weapons fit comprises four R-33 air-to-air missiles (*see* Appendix 2) semirecessed under the fuselage on AKU-410 ejector racks which before firing extend the missile below the fuselage on swinging trapezes. Alternative fits are: four R-33s plus four R-60 or R-60M on underwing pylons; or three R-33s plus two R-40TD or R-40T missiles on underwing pylons (the fourth AKU-410 carrying the R-40 control pod).

The MiG-31 was of course designed to have both radar and IR sensors. The main radar is the SBI-16 *Zaslon*, which has Service designation RP-31. This has a fixed antenna with electronic scanning, with a diameter of 1,195mm (47in), and was the first such radar to go into service anywhere. It can detect targets out to 300km (186 miles). Large aircraft can be accurately tracked at a distance of 200km (124 miles) in the forward hemisphere and 120km (74.6 miles) in the rear hemisphere. Corresponding distances for small targets (radar cross-section 2sq m, 21.5sq ft) are 90 and 70km (56 and 43 miles), respectively. This radar was extensively tested against stealthy targets, helicopters and 'hedge-hopping' cruise missiles.

It was designed to track ten targets simultaneously, whilst guiding R-33 missiles individually against the four posing the greatest threat. Threat priority allocation is performed by the *Argon*-K computer. Horizontal (azimuth) coverage is ±70°, rising in some modes to ±120°; vertical coverage elevation limits are +70°/–60°. Many missiles were fired from MiG-31s at both low and very high altitudes against targets flying at altitudes from 50m (164ft) to 28,000m (91,865ft), in each case achieving a kill.

The IRST (infrared search/track) pack is a Type 8TP, forming an element in the KOLS (opto-electronic system). It is installed in a retractable drum which can be extended under the forward fuselage. It is linked with the radar and supplies the pilot's HUD (head-up display) and WSO's displays, and enables the MiG-31 to close on its targets without using the radar. It provides target information for the R-40TD and R-60M missiles, and greatly enhances the aircraft's capability in an environment of heavy ECM. FOV (field of view) is ±60° in azimuth and +6°/–13° in the vertical plane.

The avionics suite includes the BAN-75 command-link, SAU-155M automatic flight-control system, APD-518 secure digital data link integrated with the IA-PVO's AK-RLDN secure digital ground-based network, the *Argon*-K computer, R-862 uhf radio, R-864 hf radio, RIU registration/indication device, P-591 audio (speech) warning of critical system failures or impending dangerous flight modes, SPO-155L RHAWS (radar homing and warning system), SRO-2P IFF transmitter and SRZ-2P IFF receiver, comprehensive (classified) ECCM equipment, SO-69 ATC (air-traffic control) receiver, *Tester*-UZL flight-data recorder, ARK-19 radio compass, RV-15 radar altimeter, RPM-76 marker-beacon receiver, SPU-9 intercom and MS-61 CVR (cockpit voice recorder).

The NK-25 navigation suite comprises a duplicated IS-1-72A inertial navigation system. This is built around the *Manyovr* (manoeuvre) digital processor, A-312 *Radikal*-NP (radical) or A-331 Shoran set, A-723 *Kvitok*-2 (receipt) Loran set, a *Tropik* (tropic) Loran set with an error of 0.13–1.3km (426–4,260ft) over a distance run of 2,000km (1,242 miles), and a *Marshroot* (route) Loran set with an error margin of 1.8–3.6km (1.1–2.2 miles) over distances of 2,000–10,000km. This exceptional navigation suite enables the MiG-31 to undertake extremely long flights far over the Arctic.

Most of the instruments in both cockpits of the MiG-31 were originally of the electromechanical dial type, though there has been some updating. The pilot's cockpit is equipped with a PPI-70V colour HUD (head-up display), while the WSO has a large central circular tactical-situation display, beside which are two small rectangular MFDs (multifunction displays). A unique feature of the MiG-31 is that it is possible for a flight of four aircraft up to 200km (124 miles) apart to exchange data generated by their radars via the secure APD-518. This also enables a MiG-31 to guide to targets other aircraft with less-comprehensive equipment, such as a MiG-25PD. Alternatively, a MiG-31 can guide any other kind of supersonic fighter even if it has no sensors whatever.

Full-scale production of the MiG-31, *Izdeliye* 01, began in 1979, a total of 500 being built at Gor'kiy by 1989. The MiG-31 achieved IOC (initial operational capability) in 1980. By this time USAF SR-71A aircraft had made systematic intrusions into Soviet airspace on reconnaissance with several kinds of sensor. Accordingly, four of the first operational aircraft were sent with skilled crews to the Far East. They arrived at Sokol AB on Sakhalin Island just a week after the notorious incident of 1 September 1983 when Su-15s shot a Korean Air Lines Boeing 747-230B into the sea after it had strayed far into this sensitive area. Appearance of the MiG-31 fairly quickly brought such intrusions and SR-71 overflights to an end.

Despite the loss of several aircraft during development the MiG-31 established an excellent reliability record in PVO service. Thanks to the relatively cool surface temperature of the engines there has yet to be a single case of fire in an engine bay. Approximately 320 aircraft, mainly upgraded to MiG-31B or BS, remain on IA-PVO strength, as described later. The ASCC called the MiG-31 'Foxhound-A'.

Span 13.456 or 13.464m (44ft 1¾in or 44ft 2in); length 22.688m (74ft 5¼in), (fuselage only) 20.62m (67ft 7¾in); wing area (wings, exclusive of LERX) 41.0sq m (441sq ft), (gross, including fuselage across root chord) 61.6sq m (663sq ft).

Weight empty 21,825kg (48,115lb); internal fuel 16,350kg (36,045lb); loaded (clean) 36,700kg (80,908lb), (maximum internal fuel, four R-33) 41,000kg (90,388lb), (maximum with tanks) 46,200kg (101,852lb); maximum landing weight 26,600kg (58,642lb).

Maximum speed at sea level 1,500km/h (932mph, Mach 1.23), over 17,000m (55,774ft) 3,000km/h (1,864mph, Mach 2.82); maximum Mach (external R-40TD) 2.35, (with tanks) 0.9; maximum IAS (eight missiles) 1,200km/h

(746mph), (extended periscope) 700km/h (435mph); service ceiling (four R-33) 20,600m (67,600ft); range (Mach 0.8, no tanks) 2,400km (1,491 miles), (Mach 0.8, with tanks) 3,000km (1,864 miles), (Mach 2.35, four R-33) 1,400km (870 miles), (ferry) 3,300km (2,050 miles); combat radius (typical) 720km (447 miles); endurance 3.6hr; takeoff speed 345km/h (214mph), takeoff run 950m (3,117ft); landing speed (with chutes) 285km/h (177mph); landing run 800–900m (2,625–2,953ft).

MiG-31, 01DZ

Despite its considerable improvement in range and endurance over the MiG-25, the MiG-31 was still considered to be inadequate in both respects. The regiment at Monchegorsk near Murmansk was tasked with escort of maritime reconnaissance and ASW aircraft, but had inadequate fuel for the job, and the obvious answer was to equip the MiG-31 for inflight refuelling.

The retractable probe had already been tested on MiG-25s, including the MiG-25PDZ. On the MiG-31 the probe was tested in front of the windscreen on both port and starboard sides, from where it was extended almost vertically by fuel pressure. The first MiG-31 with a probe was F/n 1603, which was fitted with a retractable probe not connected to the fuel system. Testing with tankers showed that, because of the precision and immediate response of the engine control system, no microthrottle link (as fitted to the MiG-25) was needed. Despite this, one was fitted to make pilots feel more comfortable.

The second aircraft, F/n 3608, had an operative probe but lacked certain items enabling the crew to monitor automatic transfer of fuel. The first to have the complete system was 'Blue 592' (F/n 5902). This and other aircraft were tested by OKB and NII-VVS crews from Akhtubinsk. Toktar Aubakirov flew long missions round the North Pole to test the navigation system. Roman Taskayev and WSO flew to Anadyr PVO base on the Chukotka peninsula via the Pole. On the return they flew along the entire Arctic coastline and direct to Moscow, in a nine-hour mission. Taskayev and Aubakirov, with navigator Popov, made several flights from Monchegorsk to Anadyr via the Pole, refuelling twice on each 8hr 40min mission, one practice intercept being over the Pole.

A total of about 45 probe-equipped MiG-31 *Izdeliye* 01DZ interceptors were built at the *Sokol* plant at Nizhniy-Novgorod (previously called Gor'kiy) in 1990–91. Most other MiG-31s were retrofitted. One aircraft was flown by Menitskiy and WSO Yuriy Yermakov at the 1991 Paris airshow, and subsequently at Farnborough, Berlin and Moscow airshows, in a distinctive OKB colour scheme. Data as before.

MiG-31B, 01B

From the first flight in 1975 the Mikoyan team had worked with government agencies on both a completely new weapons system and also on various updates. In 1985 a 'hired agent of a Western intelligence agency' A Tolkachev was arrested by the KGB, tried and found guilty of supplying his paymasters with detailed information on the MiG-31 weapons and avionics. This put greater pressure on the need for a MiG-31 update.

Directed by A A Belosvyet, the resulting MiG-31B *Izdeliye* 01B has an improved radar with even greater ECCM features, a new digital processor with greater memory and faster speed, and upgraded R-33S missiles. The changes are said to have enhanced operational effectiveness by 30 per cent. This version replaced the MiG-31 in production in late 1990.

MiG-31BS, 01BS

This is the designation of the MiG-31 after being put through the *Sokol* factory a second time to be updated to MiG-31B standard. This includes fitting a refuelling probe. The S in the designation indicates *stroyevoy*, operational. As noted, approximately 320 of these aircraft remain operational, though shortage of money means that serviceability and flying rates are low. Units comprise the 153rd IAP (fighter regiment) at Morshansk, 786th IAP at Pravdinsk, 180th IAP at Gromovo, 174th IAP at Monchegorsk, 72nd IAP at Amderma and the 518th IAP at Talagi. Crews are trained at the IA-PVO Fighter Weapons School at Savostleyka. Data unchanged.

MiG-31 modified

As in the case of some earlier MiG aircraft, the Gor'kiy factory's own design team took a keen interest in the aircraft they were building and studied ways of improving it. Since they did not have authority to build aircraft that had not been ordered they decided to modify an existing one. Under chief designer Mindrov, MiG-31 'Blue 503' was completed with several modifications, mainly concerned with increasing fuel capacity. The bulkheads between Tanks 1 and 2 and between 5 and 6 were deleted, running the tanks together. It was found that centre of gravity shift caused stability problems, but '503' later became a testbed in the MiG-31M programme.

MiG-31D, 07

In 1987 the OKB factory in Moscow built or rebuilt two prototypes of this experimental version. Their callsigns were 'Blue 071' and '072'. The standard weapons system was deleted and the R-33 recesses faired over. Instead a fuselage pylon was fitted to carry a single very large missile. To prevent serious degradation of yaw stability with this missile in place the LERX were enlarged (similar to the MiG-31M) and the wingtips were fitted with large delta fins similar to those of the MiG-25P prototypes. 'Blue 072' was extensively tested from Zhukovskiy by OKB pilots, but the project was suspended in the early 1990s.

MiG-31 testbed

The designation of this has not been published, but the common designation of Russian testbed aircraft is LL from *letayushchaya laboratoriya* (flying laboratory). This aircraft – formerly series MiG-31 'Red 79' – has a bald lion painted on the nose. It is currently the fastest testbed available for ejection seats, which are fired from the rear cockpit. Black calibration markings are painted on the intakes, and cine cameras are installed in cigar-shaped wingtip pods. Though based at NII-VVS Akhtubinsk, this aircraft was statically displayed at MosAero-92 at Zhukovskiy. In September 1995 it celebrated the NII-VVS 75th anniversary with a live seat ejection during the takeoff on the runway at Akhtubinsk.

MiG-31E

With this designation a version of the MiG-31 has been developed for export. It is fitted with a suitably downgraded *Zaslon* radar and simplified R-33 missiles, as well as pairs of unchanged R-60 or R-60M dogfight missiles. The avionics, especially the ECM installation, are also simplified. Despite the reduced specification, this aircraft still has what are believed to be unmatched capabilities in the interception role, including the ability to guide large numbers of simpler fighters which otherwise could not find targets.

In May 1992 Russia struck a deal with China for delivery of twenty-four probed MiG-31E aircraft to the PLA air force. The first five were to be delivered by the following month, and licence production by Sheyang Aircraft Industry Co was to begin in late 1994. Nothing more has been heard of this, but in 1997 a MiG-31E prototype, 'White 903,' was on test at Akhtubinsk.

MiG-31F

Not yet built, this projected fighter/bomber version was unveiled by the OKB at the 1995 Paris airshow. Designated from *frontovoy* (tactical), it would be capable of using most of the current Russian air-to-ground weapons. It could operate in the antiradar role carrying Kh-25MP and/or Kh-31P. It could carry out antishipping strikes using Kh-31A. Other attack missiles could include two TV-guided Kh-59s or Kh-59Ms, or three lighter Kh-29L or Kh-29T. Alternatively it could carry guided bombs, such as three laser-guided KAB-1500L or TV-guided KAB-1500TK or light (1,100lb) KAB-500KR bombs. One attachment would be used for a TV/laser pod. Maximum bomb load would be 9,000kg (19,841lb), made up of six of the 1,500kg weapons.

In late 1997 about 330 MiG-31 aircraft to various build-standards remained in service with Russian Air Defence Aviation. The MiG-31M and 701 MDP having been essentially abandoned, consideration is being given to bringing most of the surviving force up to MiG-31F standard, though this would demand a large training effort to convert interceptor pilots to the air/ground role. This is likely to be needed anyway, with the planned merger of Air Defence with Frontal Aviation.

MiG-31FE

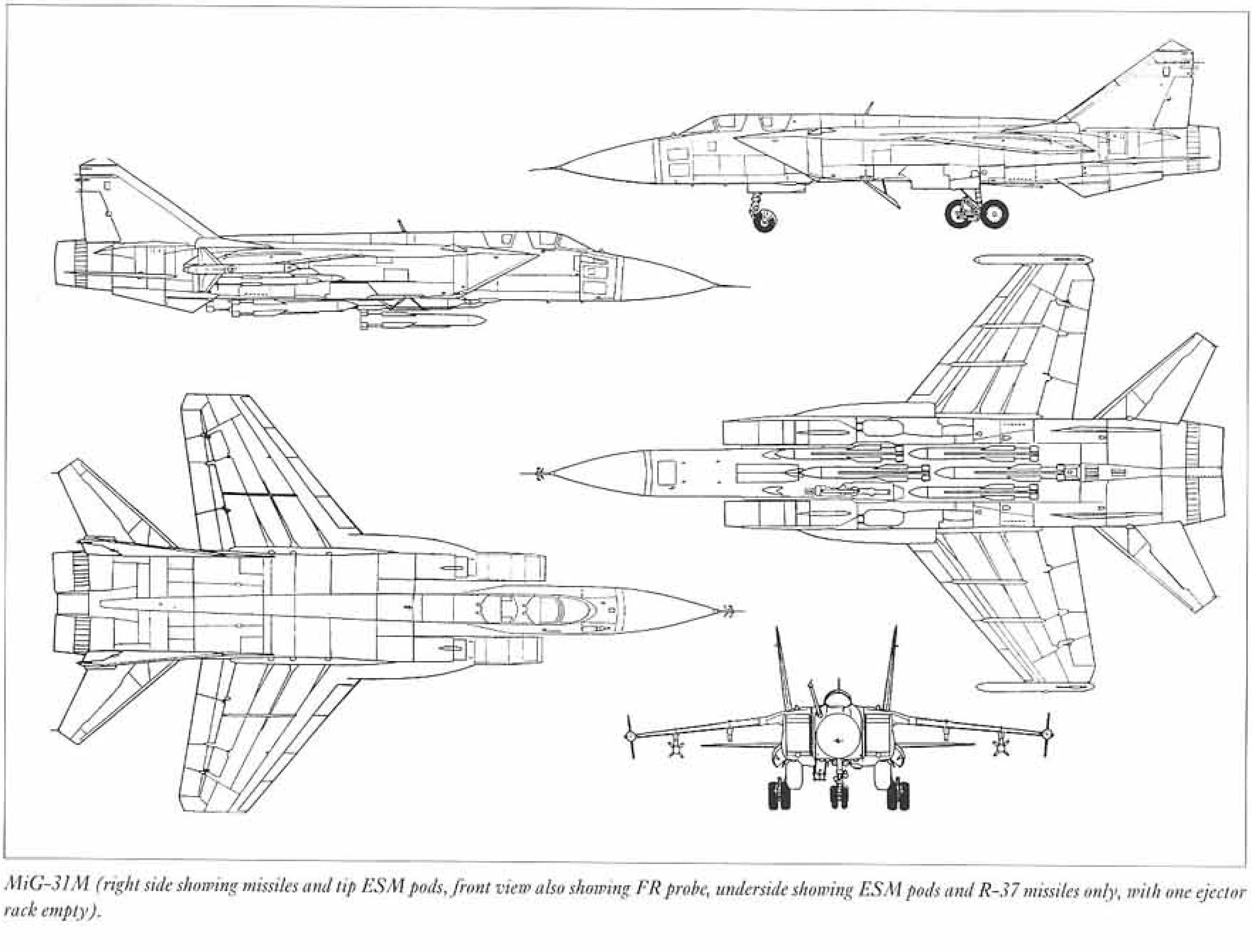
This is the designation of a planned export fighter/bomber. It would have provision for Western avionics and/or weapons, depending on customer preference.

MiG-31M, 05

After having been in development for eight years, this much-modified aircraft emerged publicly in 1985. Although at first glance differences look minor, in fact the basic aircraft has been modified almost as much as the avionics and weapons, though it is the latter which are responsible for the dramatic increase in mission capability.

One of the major changes is to fit the *Zaslon*-M radar. This has considerably increased transmitter power and greater discrimination achieved through a much greater number of elements in the electronically scanned antenna. This has a diameter increased to about 1.3m (51in), though almost all figures relating to the MiG-31M *Izdeliye* 05 are classified. To prevent the bigger radome from seriously degrading pilot view the whole antenna and radome is aligned 7° downwards, without affecting aerodynamic drag.

The *Zaslon*-M has a detection range against typical targets (obviously they have to be at high altitude because of the Earth's curvature) of 360km (224 miles). It has a typical target kill range of 200–230km (124–143 miles), and



MiG-31M (right side showing missiles and tip ESM pods, front view also showing FR probe, underside showing ESM pods and R-37 missiles only, with one ejector rack empty).

can track many targets whilst simultaneously guiding missiles against the six posing the most serious threat.

This increased range makes it possible to use a missile with even greater performance than the R-33. Vympel's R-37, the most capable AAM in service in the world (by a huge margin), switches on an active homing system to guide it over the final part of its trajectory to the target. It is longitudinally unstable, like some of the latest fighters, to increase its power of manoeuvre. Six can be carried under the fuselage in tandem groups of three on swing-down parallel-link trapezes. As a maximum load option the MiG-31M can also carry four R-77 (also called RVV-AE) missiles on the four wing pylons. These again have exceptional manoeuvrability conferred by the unique 'eggbox' control surfaces and body lift.

The gun, which is considered unlikely ever to be used in anger, has been deleted. The KOLS opto-electronic system has a new combined IRST and laser. Surprisingly this package is not retractable but removable.

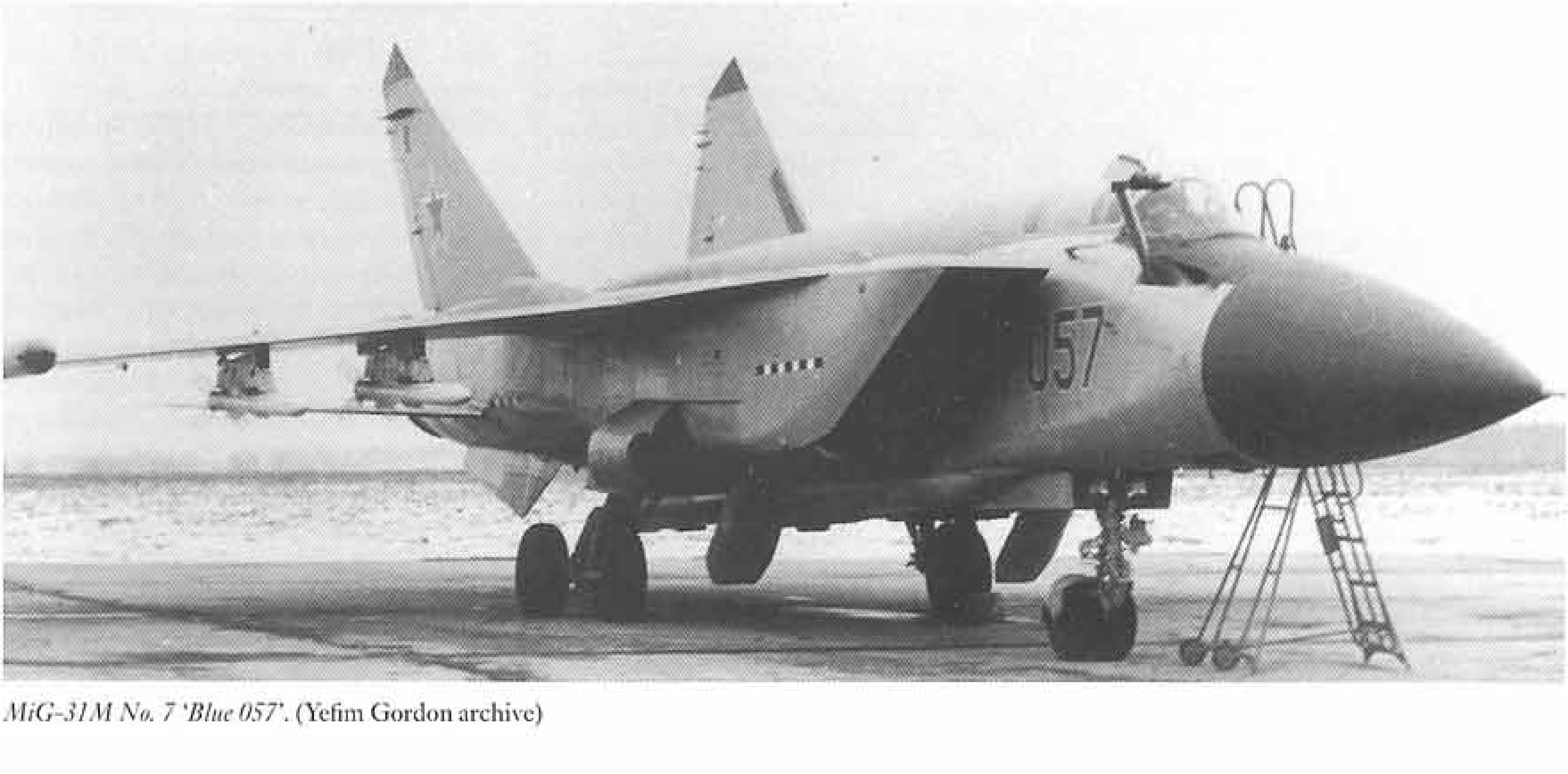
While the pilot's view has been improved, that for the backseater has been almost eliminated. The pilot now has a frameless windscreen of curved polycarbonate, designed to be birdproof. In contrast, as the WSO no longer has a set of flight controls, he has no periscope and no view out except through a small window on each side. Behind his smaller canopy the spine has been enlarged throughout its length, housing 300 litres (66gal) additional fuel, but at the rear it tapers to nothing instead of into a parabrake container. The LERX are larger and of different form, with a curved front and sides aligned with the longitudinal axis (90° sweep).

The wing fences no longer extend to the leading edge but are reduced in height and extend only across the top of the wing box between the spars. At the tips the trailing edge is cropped at a Mach angle (i.e., outboard of the flaperon it is sharply tapered) and on the tip can be added a tubular container for ESM antennas, with symmetric upper and lower delta fins reminiscent of those of some Ye-155P prototypes. The alternative is a straight tip aligned with the longitudinal axis with flush antennas at front and rear.

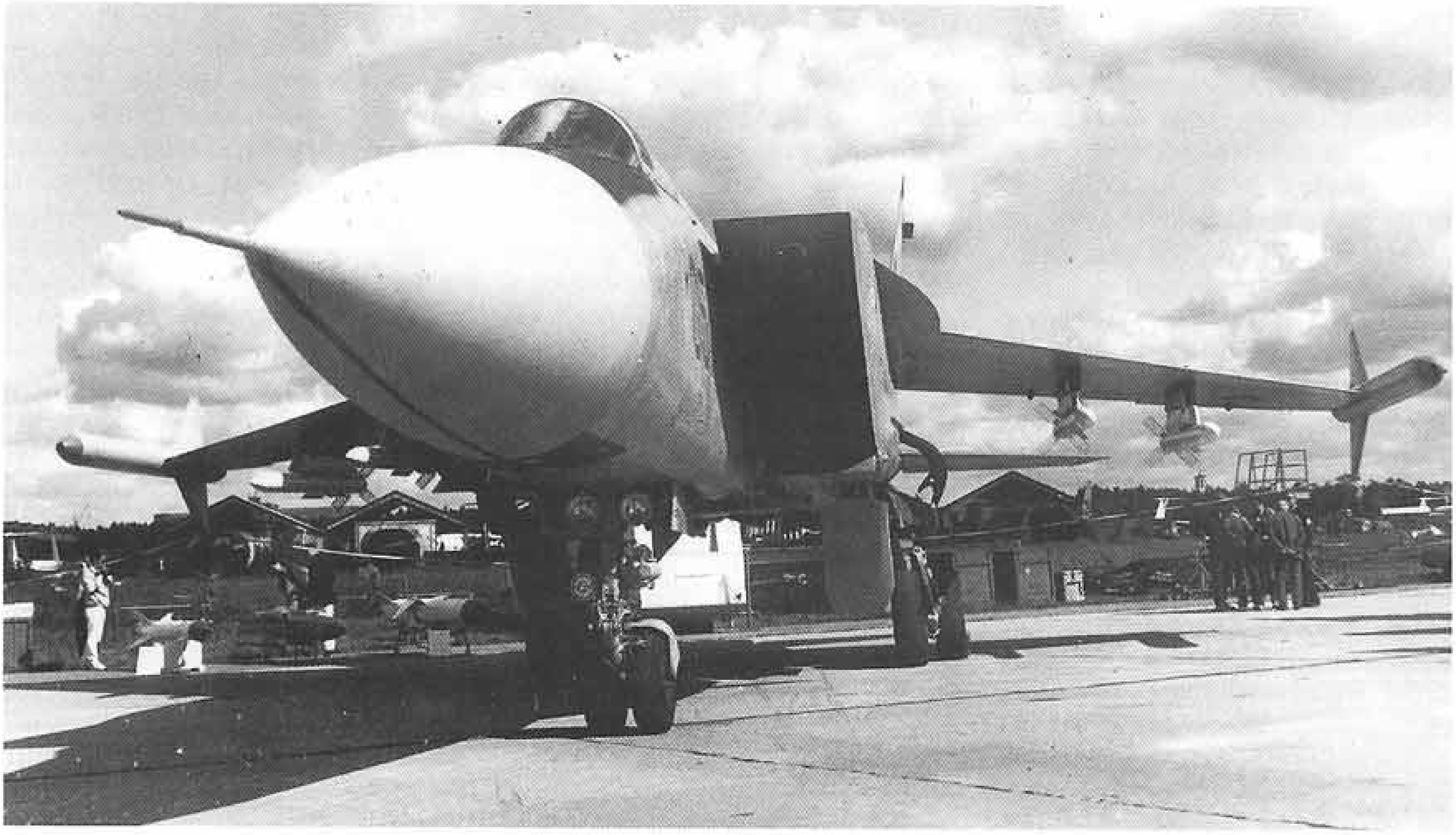
To counter the increase in takeoff weight (believed to be 52,000kg, 114,638lb) the engines of the MiG-31M are the D-30F6M, with increased thrust ratings (classified). These engines have longer convergent/divergent nozzles which are one reason why the overall length of the aircraft is no longer measured from the aft tips of the tailplanes. The tail has been modified, the fins being slightly raised by being mounted on bulged root fairings, and the rudders increased in chord with less sweep on the trailing edge. The fin roots do not extend under the rudders, which are now 0.23m (9in) clear of the engine nozzles. The nose landing gear retracts into a bay closed solely by the two side doors, and the three forward-facing lights have accordingly been repositioned on the leg itself. Finally, the flight-refuelling probe has been moved to the starboard side, and extends complete with a piece of fuselage skin.

Extensive as these modifications are, the most important concern the avionics. Apart from the brief details already given, and the fact that the MiG-31M is wholly digital, information is classified. Of course, the dial instruments have almost disappeared from the cockpits, and the WSO has four multifunction displays. In view of the cost of designing and debugging such equipment, the system probably bears some relationship to that of the MiG-33 or MiG-35.

Of course the MiG-31M was of great interest to the PVO, and a test batch was ordered from the Gor'kiy plant. The first was a static-test airframe, F/n 050101. The first flight article was the second airframe, 'Blue 052', which was first flown by Orlov and Popov on 21 December 1985. This aircraft crashed on 9 August 1991. The remainder, 'Blue 053–057', were flown to NII-VVS at Akhtubinsk as each was completed. The finned ESM pods were attached to 'Blue 057' and occasionally on others. It was found that an extra *Zaslon*-M radar had been manufactured. This 'eyes-without-a-face' situation was rectified by getting Mikoyan to build a MiG-31M forward fuselage, which was then sent to Gor'kiy and grafted on to 'Blue 503', the MiG-31 which had been unsuccessfully modified at Gor'kiy. Reborn as 'Blue 051', this hybrid has the big spine, but lacks the MiG-31M weapon system, LERX and fin fillets.



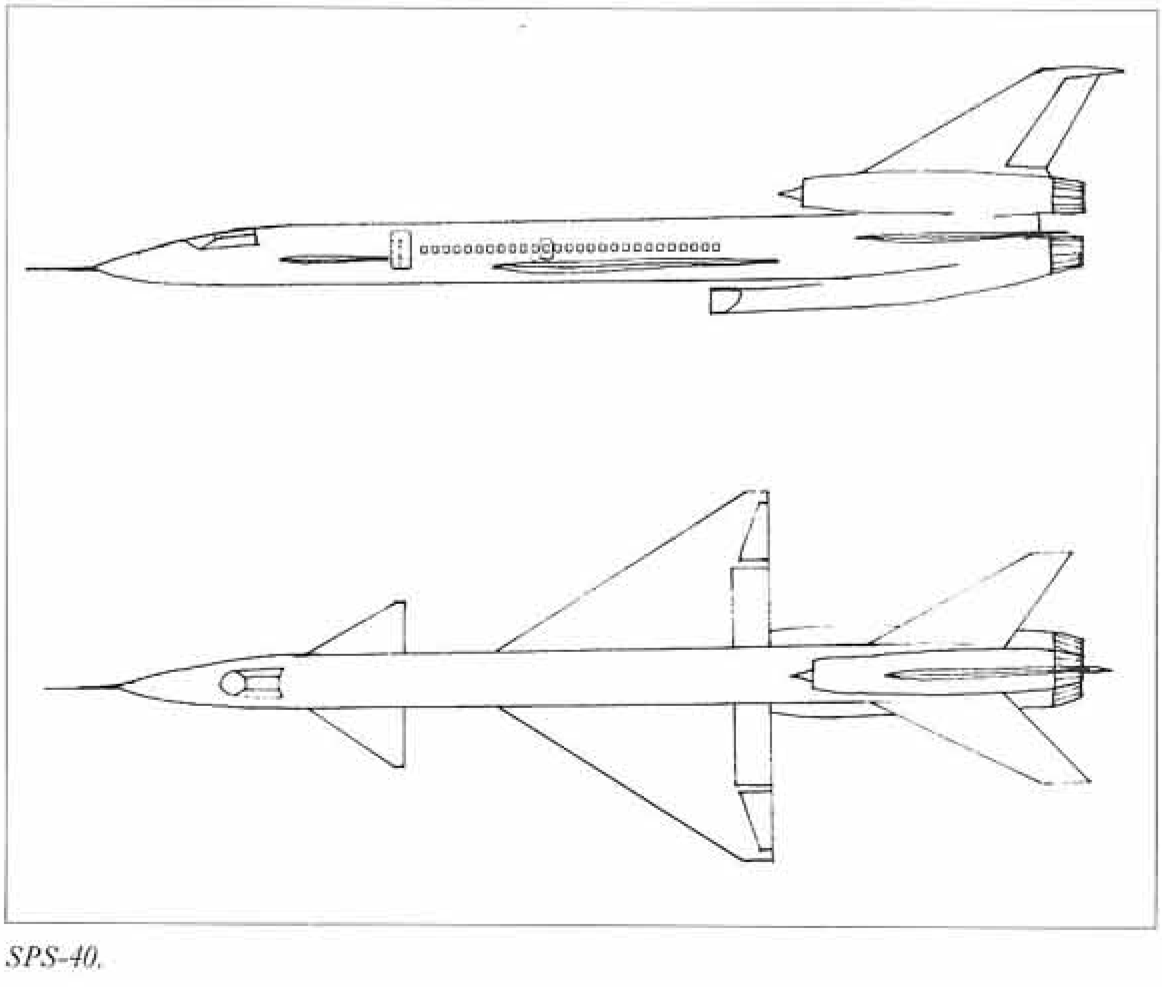
MiG-31M No. 7 'Blue 057'. (Yefim Gordon archive)



MiG-31M No. 7. (photograph by Yuriy Popov)

In March 1992 'Blue 057' was among the latest combat aircraft shown to the leaders of former Soviet republics at Machulischi airbase. In April 1994 President Yeltsin sent a telegram to the Mikoyan OKB extending congratulations for the successful development of this aircraft. He particularly praised a successful interception of a manoeuvring target at a range of 'more than 300km' (186 miles). So far as is known, no other aircraft can emulate this feat. 'Blue 057' briefly appeared at MAKS-95 and MAKS-97 airshows at Zhukovskiy.

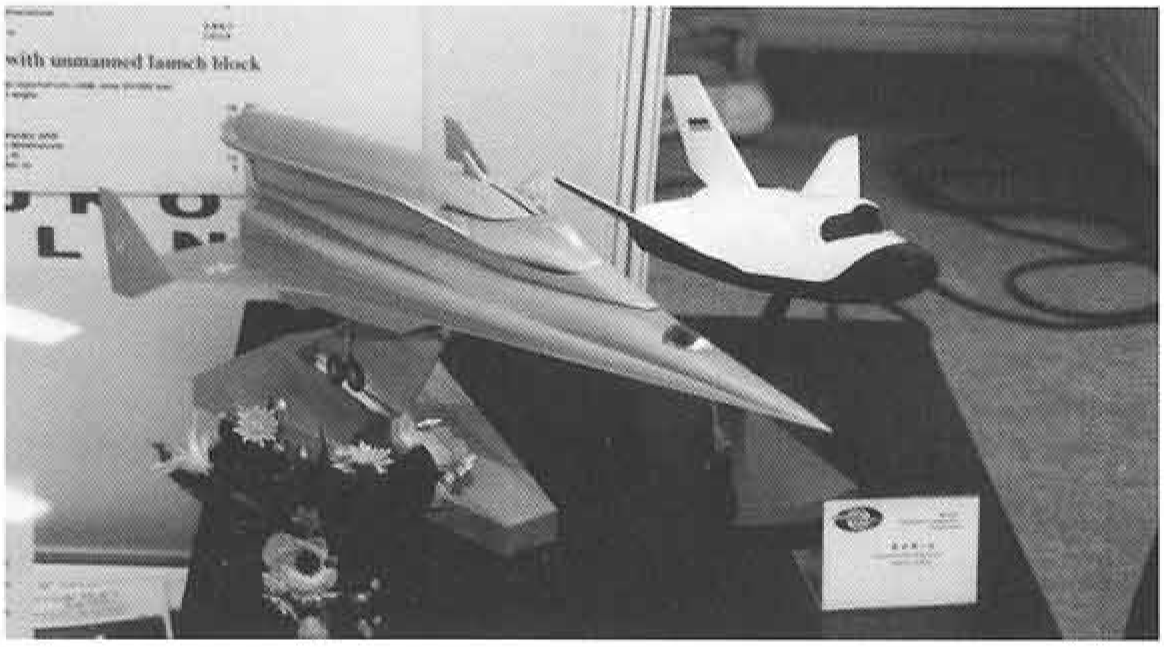
Under great difficulty a little work is continuing, and the *Sokol* plant at what is now Nizhniy-Novgorod has formally linked with MAPO-MiG and is trying to preserve the MiG-31M tooling. So far (late 1997) the Russian air force has no money to purchase any. If it becomes operational even a small number would make a dramatic difference to the ability of the PVO to cope with threats, including cruise missiles and stealth aircraft. The ASCC call the MiG-31M 'Foxhound-B'. Specifications are classified.



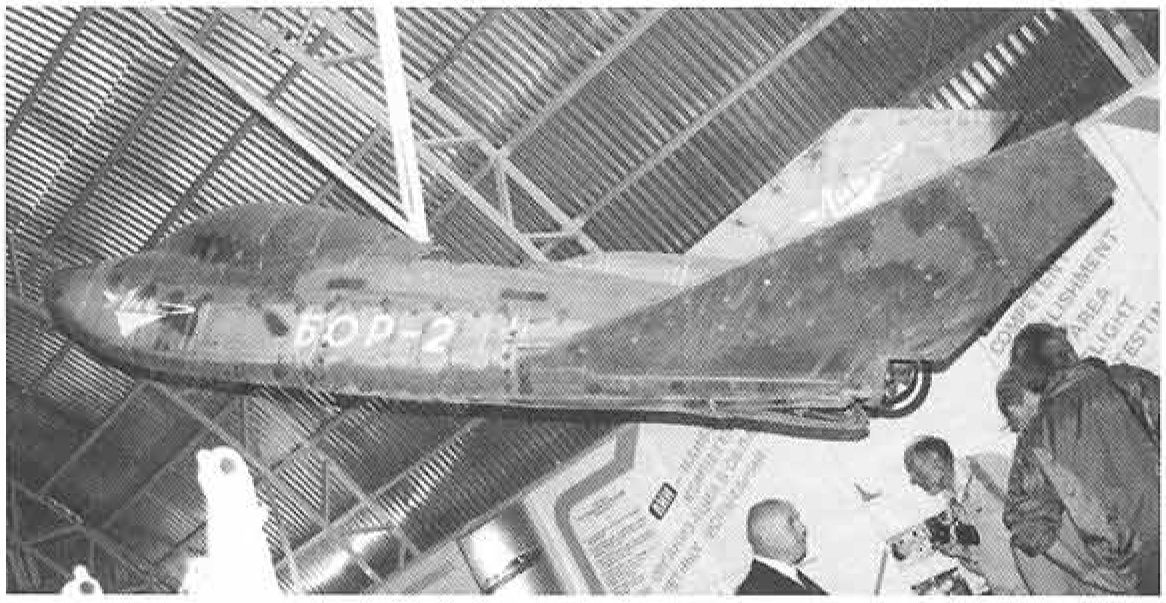
SPS-40.

SPS-40

Back in 1960 the OKB, which had never been active in the civil field, took the astonishing step of spending its own money to study a small supersonic passenger aircraft. The SPS-40 designation stemmed from 'supersonic passenger aeroplane, 40 passengers'. Chief designer was Yakov I Seletskiy. Its configuration was the unusual one of a canard delta which also had a horizontal tail. The wings would have been attached on each side to multiple ring frames, leaving the pressure cabin clear of spars. The engines were to be three R-21-300 afterburning turbojets, of the type fitted to the two Ye-8 prototypes. The two lower engines were to be fed by a two-dimensional wedge-type intake



Models of 50-50 and BOR-3. (RART)



Actual BOR-2 vehicle. (RART)

under the rear fuselage, and the centre (upper) engine was to have a circular inlet with an axially sliding centrebody. No data have been found.

Spiral

From the early 1960s the huge Soviet spaceflight effort had included testing various lifting-body vehicles, mostly fired by large rockets on ballistic trajectories and recovered from the sea. By 1965 studies had begun to include manned aerospaceplanes, winged spacecraft which, even if launched vertically by rocket, could re-enter the atmosphere and make a normal landing, to be refurbished for reuse. Following President Brezhnev's termination of the V Chelomey (OKB-52) shuttle-type aerospace-plane in 1965, Mikoyan and Sukhoi were invited to propose replacements.

On 26 June 1966 the OKB was assigned a contract for a space programme called *Spiral*, or *Izdeliye* 50-50. This comprised a huge supersonic carrier aircraft of tailless-delta form, which would take off and land like a conventional aircraft but would have the capability of reaching hypersonic speed – Mach 7 was intended – outside the atmosphere. On its back would be carried a small orbital vehicle, *Izdeliye* 50. Takeoffs and landings were planned to be at Baikonur kosmodrome.

Mikoyan appointed Gleb Y Lozino-Lozinskiy leading engineer on this challenging project. Initially a number of simple aerodynamic shapes called BOR (*bespilotniye orbitalniye raketoplan*, pilotless orbital rocket plane) were launched by large rockets from Plesetsk kosmodrome near Arkhangelsk to re-enter and be recovered by parachute on the Kapustin Yar range near the Caspian Sea. These helped to establish an overall configuration, which resembled rival US shapes of the same period such as the Northrop lifting bodies and Dyna-Soar. The next phase was to test a small manned orbital vehicle, described next.

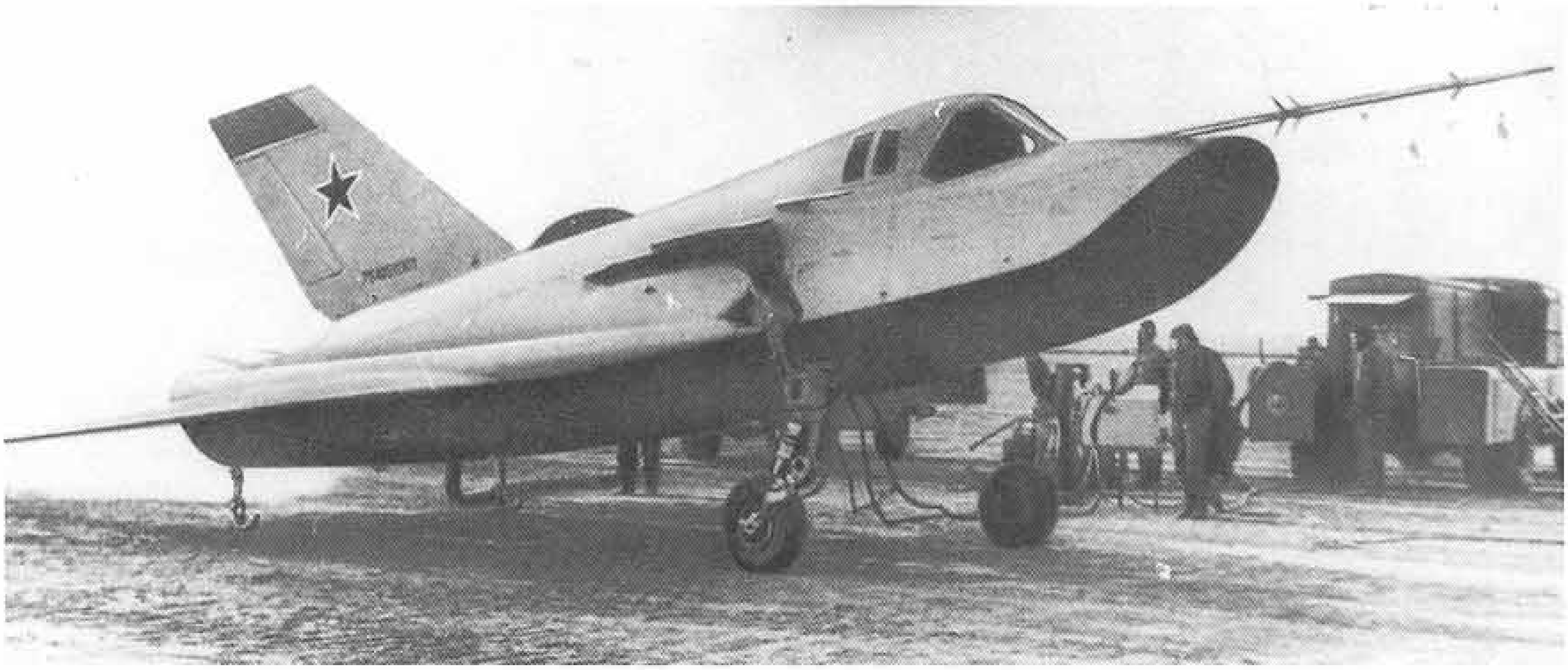
Epos

Again, Lozino-Lozinsky was leader of the project, and he directed the design of a small manned suborbital (potentially multiorbit) test vehicle. It was named *Epos* (an epic narrative or poem). The basic form of *Epos* was decided within a few weeks as a tailless delta similar to the BOR vehicles. The wing had a leading-edge sweep of 78°, and the trailing edge was fitted with elevons. The large (1.7sq m, 18.3sq ft) fin and rudder had a leading-edge sweep of 60°. The broad 'waverider' fuselage had a flattened underside of heat-resistant material, the main area being covered with refractory tiles able to withstand the severe conditions of re-entry.

A single-seat cockpit was put at the front, rocket propellants amidships around the centre of gravity, and a turbopump-fed rocket engine of 1,500kg (3,307lb) thrust at sea level (about 1,800kg, 4,000lb in space) at the rear. A total of sixteen small rocket thrusters were to provide attitude and trajectory control in space, after release from the *Spiral* carrier. Two airbrakes hinged up from the tail end of the fuselage, and the landing was to be made on four retractable skids. Flight controls were to be powered by actuators using current from batteries. One of the remarkable features was that the wings were designed to be hinged to the fuselage and to be driven by irreversible electrically powered ballscrews to any dihedral angle from zero to +30°.

105-11

The Mikoyan OKB considered it prudent to begin actual manned tests by exploring handling within the atmosphere, after re-entry, with a simple low-speed vehicle. This was designated *Izdeliye* 105. Vehicles



105-11 preflight check. (RART)

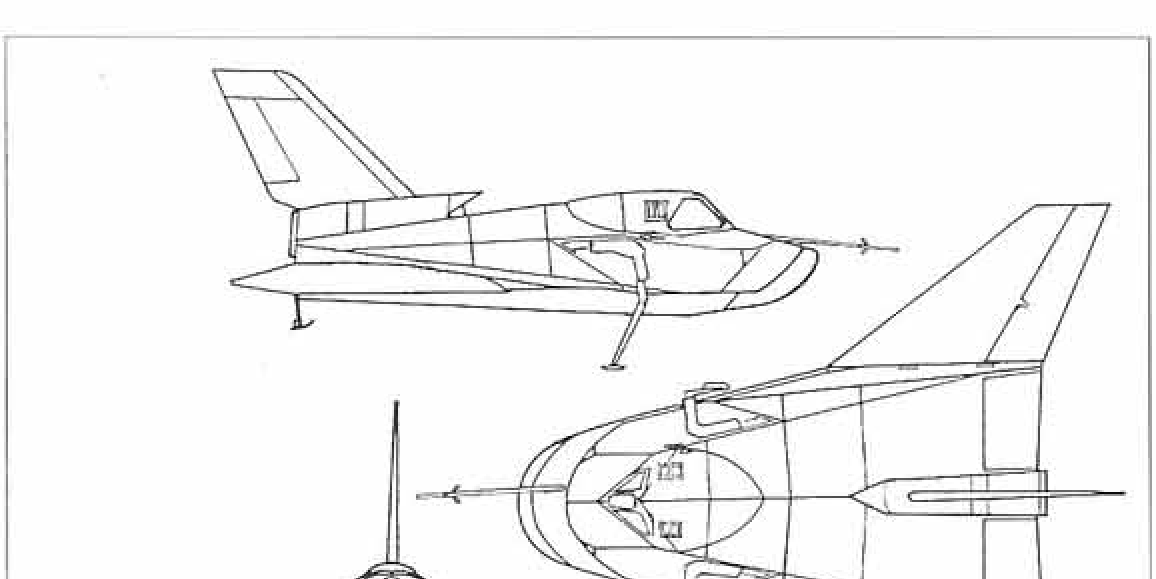
105-11, -12 and -13 are believed to have been constructed. They were intended to explore handling at Mach numbers up to 0.8 within the atmosphere during the approach and landing.

Aerodynamically the 105 generally resembled *Epos*, apart from having an RD-36-35K turbojet of nominal 2,350kg thrust but derated to 2,000kg (4,409lb) installed in the rear fuselage at the base of the fin. It was decided to omit the small reaction control nozzles, and to fly the 105-11 manually using the elevons and rudder. The cockpit was conventional instead of being a jettisonable capsule, and instrumentation was served by a long air-data probe above the nose, a total temperature/pressure probe on the right of the canopy and an AOA vane on the left side. As in the projected orbital craft, much of the fuselage was covered in removable access panels, screwed on to the underlying structure which carried all stresses and could accommodate thermal distortion (which was not expected with the 105-11).

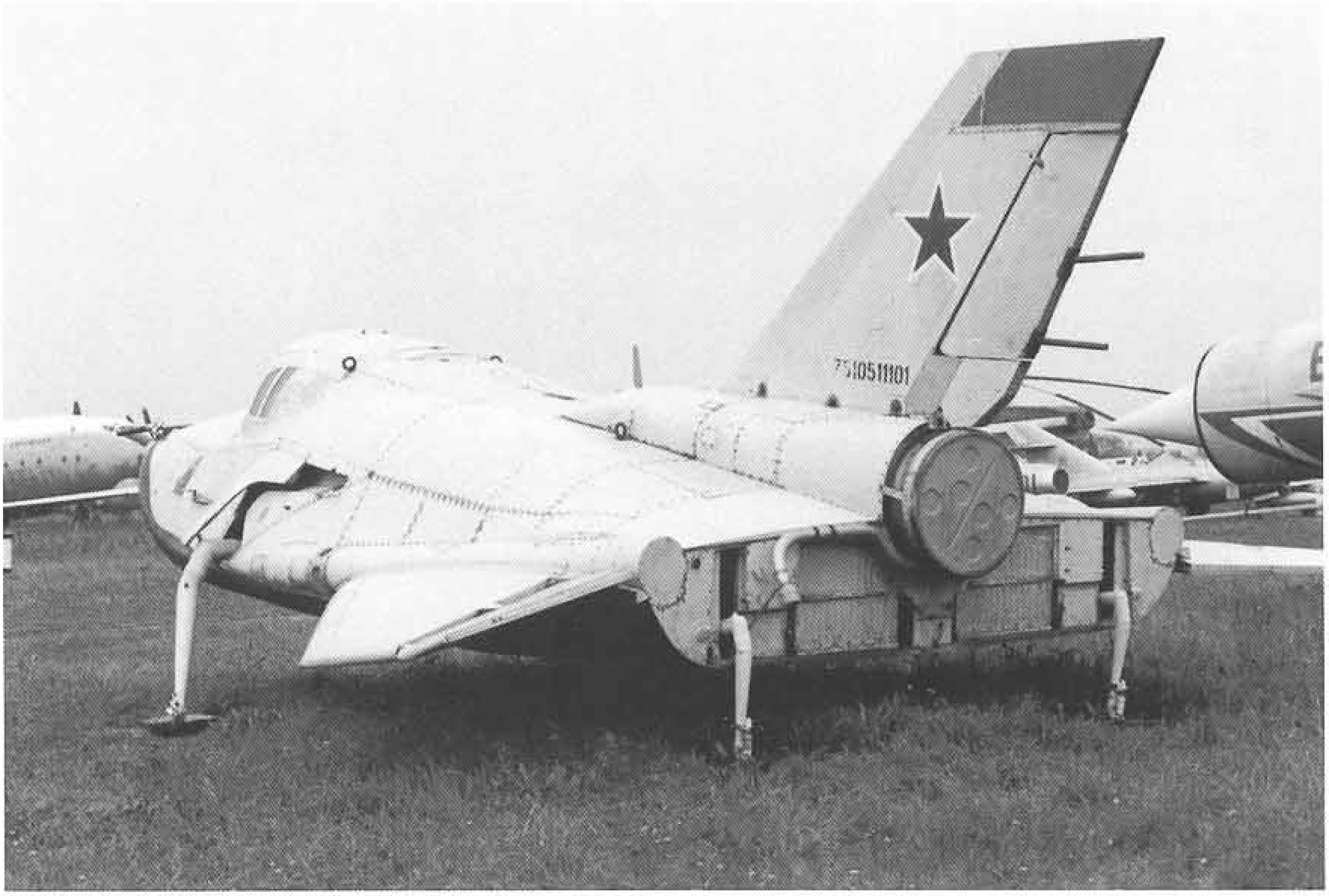
These test vehicles were made in the OKB prototype shop. The only one to fly was 105-11 (F/n 7510511101). Like the *Epos*, it was designed to be launched from a carrier vehicle, but in this case an aeroplane. Accordingly, the engine inlet was fitted with an upwards-hinged cover to fair it over until the engine was started. In 1975 the engine was tested at CIAM with a dummy fuselage and inlet system over the expected range of angles of attack and sideslip. In September 1976 the assigned OKB pilot, Aviard Fastovets, began high-speed taxi tests at Zhukovskiy, the two front landing legs having the steel skids replaced by rubber-tyred wheels carried on trailing links, the rear skids being left unaltered (according to an OKB story, using crushed melons along the runway as lubrication). On later runs the 105-11 was lifted off, and handling explored just above the ground.

On 11 October 1976 Fastovets took off, climbed straight ahead to 560m (1,837ft) and landed at another airfield about 19km (12 miles) away. On 27 November 1977 Fastovets got aboard the 105-11 attached under the OKB's Tupolev Tu-95K (previously used for cruise-missile development) and released at 5,000m (16,400ft). He landed without difficulty on an unpaved strip, all four legs having skids. The 105-11 made seven further air-launched flights, ending in September 1978. These showed that stability and control in subsonic atmospheric flight were satisfactory. Accordingly, work went ahead on the manned aerospace aircraft.

This was, of course, *Buran* (snowstorm), designed under the leadership of NPO Molniya in Moscow. In 1976 Lozino-Lozinsky, then 67 years old, left the MiG OKB to become general director of the Molniya team. In fact *Buran* resembled the US Space Shuttle rather than the 105, but the MiG



105-11.



105-11 at Monino. (RART).

research craft was instrumental in solving some of the basic problems. Today 105-11 is stored out of doors at the VVS museum at Monino, parked behind the MiG bureau's Tu-95K which carried it aloft.

Span 6.7m (21ft 11¾in); length (excluding PVD) 10.6m (34ft 9⅝in); wing area 6.6sq m (71sq ft); area of wing and lifting body 24sq m (258sq ft).

Weight empty 3,500kg (7,716lb); fuel 500kg (1,102lb); weight loaded 4,220kg (9,300lb).

Maximum Mach number 0.8; landing speed 250–270km/h (155–168mph).

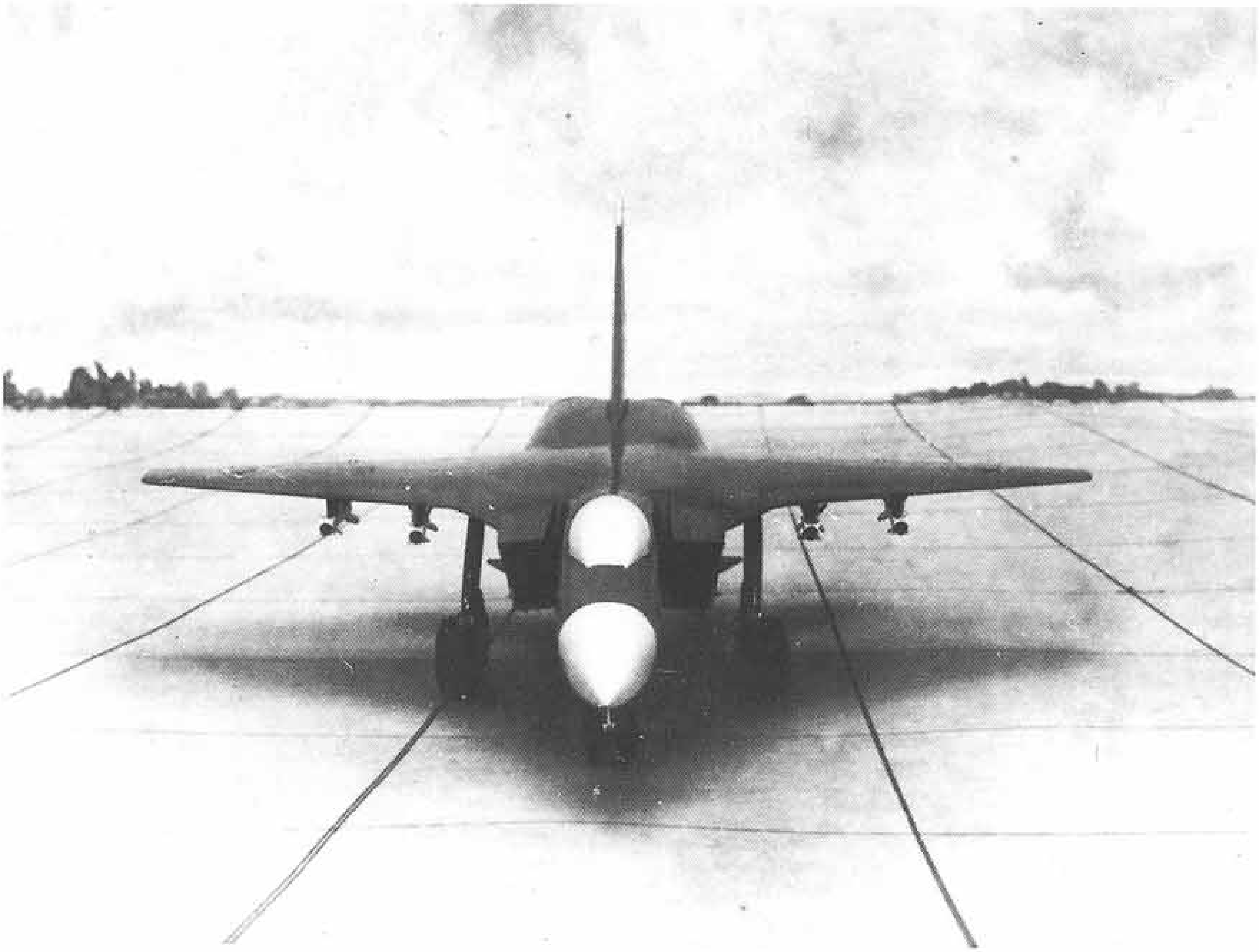
MiG-29

Begun in 1970, when the mighty Soviet military-industrial complex produced some of the finest weapons in the world, the MiG-29 has bridged the transition to the post-Communist era in which lack of money has virtually brought such endeavours to a halt. In the 1980s on almost every count, against targets at short to medium ranges, the MiG-29 was the best fighter in the world. It also had a useful capability against surface targets. Today it is dramatically better still, but of the three MiG-29 production lines two no longer exist and the third has almost come to a halt, and relies upon export orders. Even more unbelievably, the totally different next-generation successor has had to be abandoned, because no money can be found to continue the programme.

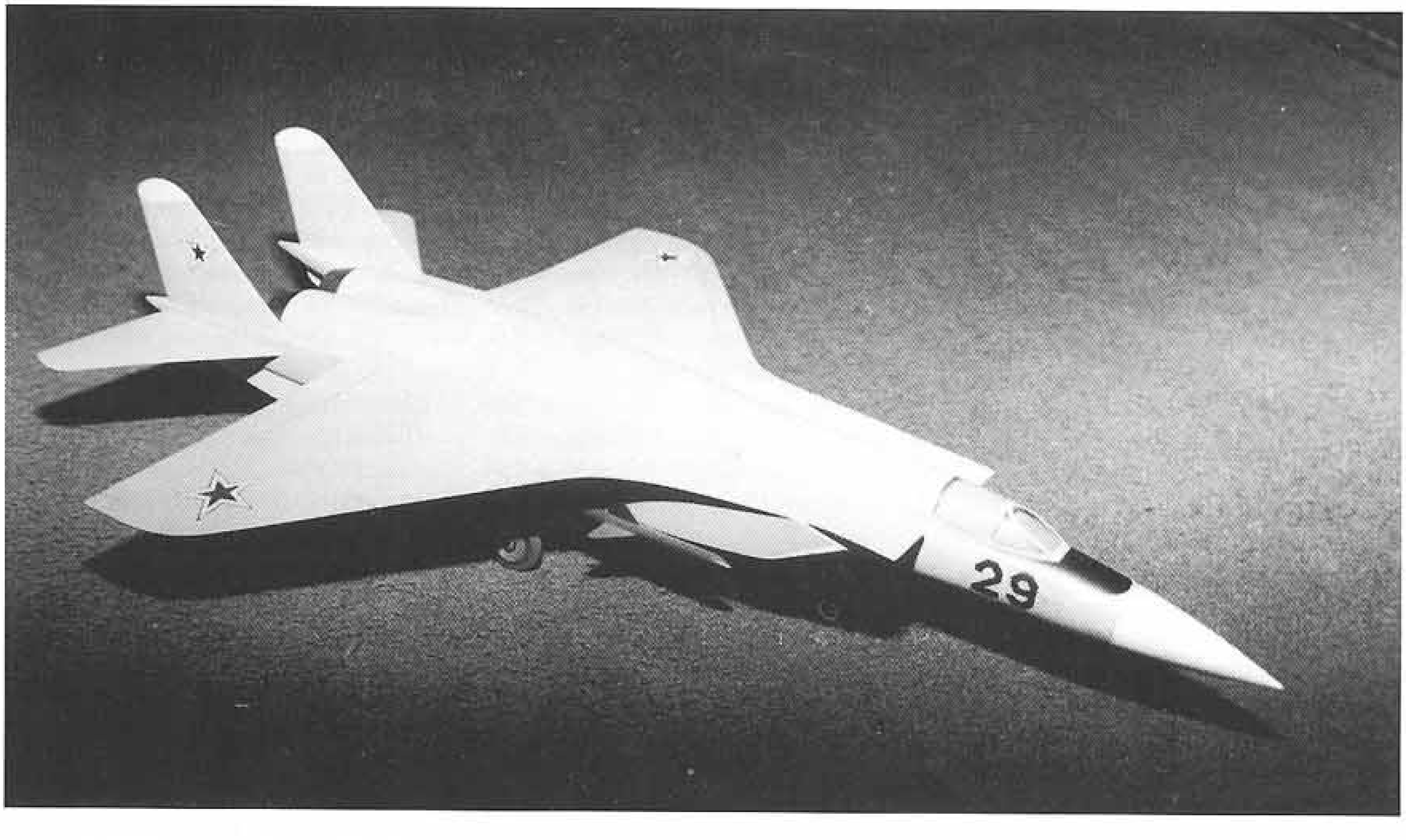
Things were different in 1970, when the principal founder of the OKB died and was replaced by Rostislav Apollosovich Belyakov. He had become *de facto* general designer earlier in the year, when Mikoyan had been crippled by a heart attack, and had immediately authorized a series of studies for a new agile fighter – LFI, *lyogkiy frontovoy istrebitel'*, light front-line fighter – in the tradition of the MiG-15 and MiG-21. Over forty parametric studies quickly settled on the use of twin engines side by side fed by lateral inlets, but it was more difficult to decide on the wing and tail.

Of course, the Mikoyan project team did not work in isolation. From the outset they collaborated with the VVS and MAP, and with the aerodynamicists at CAHI. In parallel, work went ahead to provide a suitable engine, radar, missiles and gun. The eventual winner of the engine contract was what is today named for the founder, Vladimir Klimov, and their RD-33 afterburning turbofan is described in Appendix 1. The RD-33 was designed from 1968 and first ran in 1972, in which year Mikoyan received the first design contract for the new fighter. Chief designer of the MiG-29 was A A Chumachenko, who in 1982 was replaced by Mikhail Romanovich Waldenburg, assisted by V A Lavrov.

Together with CAHI the Mikoyan designers based the aerodynamics on integration of the fuselage, engine installations and wing to give maximum lift over an unprecedented range of angles of attack. The lift from the fuselage, which had been important in the MiG-25 and MiG-31, was taken further, and in early configurations was augmented by lift from the inlet ducts. The logical result was the emergence of a *centroplan*, a broad blended wing/fuselage forming the structural heart of the aircraft. This



Model of MiG-29 project. (Yefim Gordon archive)



Model of MiG-29 project. (photograph by Yefim Gordon)

R A Belyakov with model of MiG-29 project. (Yefim Gordon archive)

had been seen twenty years earlier in the Swedish Saab Draken, and, in parallel with the MiG aircraft, was to be seen in a more timid form in the General Dynamics F-16.

By 1973 it was certain that the outer wings would not be pivoted for variable-sweep but fixed, and most studies tended to resemble smaller versions of the MiG-25 and MiG-31 but with a proportionately larger wing with an ogive curved leading edge. Photographs show models of this period, one with large single mainwheels and fin and the other with paired mainwheels and fins.

This second model showed a new feature. As in the MiG-25 and MiG-31 the inlet ducts passed under the wing and curved inwards to feed two engines close together, but in this project the propulsion gondolas were quite separate, and each was continued straight back in the form of a strong beam outboard of the engine to carry the tail. Each beam carried one vertical tail and one horizontal tail on its outboard side.

A third model shows a configuration that had much to commend it, a tailless delta. This made the *centroplan* almost the whole aircraft, and gave the largest wing area of all. The engine inlets had now moved back under the roots of the wing behind the highly swept leading edge, where the wing immediately above guided air into the inlet at large angles of attack. Because they could be mounted anywhere on the wing, the vertical tails in this project were far apart (*see* photograph above).

By 1975 the project had taken on its definitive form, which has proved to be outstanding in all respects. On a slightly larger scale, a very similar shape was adopted by Sukhoi for the T10-1 prototype which led to the Su-27, though this had the vertical tails above the engines. Later Sukhoi prototypes had the vertical tails moved outboard, exactly resembling the Mikoyan aircraft.

By 1975 it was clear that the intended radar, the *Sapfir*-29 (N019) being developed by Fazotron, would not be ready in time for early MiG-29 prototypes. As a major project, the MiG OKB planned a MiG-29A, to be fitted with *Sapfir*-29A radar, but this was never built. To avoid confusion between prototypes and *Izdeliye* (product) numbers, the following is a brief review.

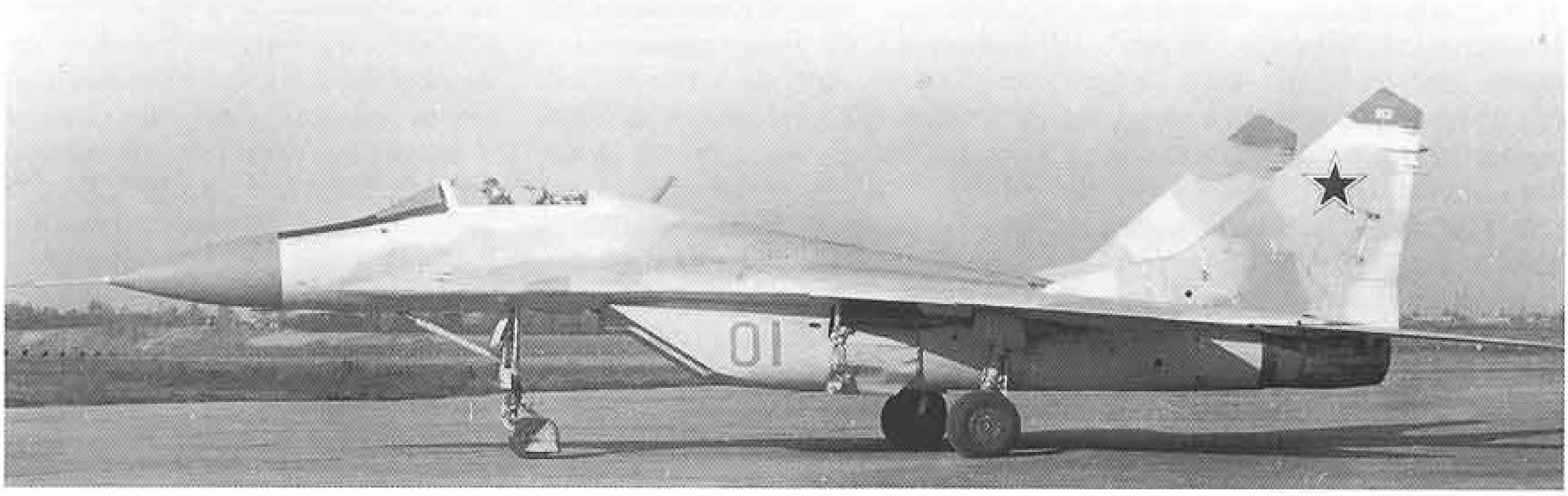
Prototypes: 901, 902, 903, 904, 908 (replacement for 903), 917, 918 (first with radar) and 919–925.

Izdeliye numbers: 9-12 (MiG-29), 9-12A (Warsaw Pact), 9-12B (other exports), 9-12S/SD/SM, 9-13, 9-13S/SE, 9-15 (MiG-29M), 9-17 (MiG-29SMP), 9-31 (MiG-29K) and 9-51 (MiG-29UB).

To avoid repetition, the following is a description of the 901 prototype, which provides a basis for subsequent developments.

901

This was the first prototype. Approximately 40 per cent of the lift was obtained from the *centroplan*, the blended inner wing and fuselage between the fins. Over this portion the leading edge had a generous radius and sweep angle of 73° 30′. The outer panels (the wings proper) had a sharper leading edge swept at 42° running in a straight line to a squared-off tip with a chord of 1.27m (50in). Aerofoil profile of the outer wings was



901, MiG-29 first prototype. (OKB)

symmetric with a thickness/chord ratio of 4 per cent, and anhedral –2°. The leading edge over each outer wing comprised hydraulically driven droop flaps in five sections, and in most (but not all) photographs of 901 on the ground the first and fifth sections are drooped 1°. The leading edge was computer-controlled and linked by the SAU-451-02 autopilot to the two-section hydraulically driven plain flaps to vary wing camber according to the demands of flight speed and manoeuvre load. Outboard of the flaps were two-section powered ailerons, with ground-adjustable trailing-edge 'knife' strips, extending to the removable tips.

The fuselage was unusual in that above the *centroplan* it swiftly tapered away to nothing. Nearly all the fuel and equipment was housed in the *centroplan*, while the complete propulsion systems were slung underneath. Reading from the front the sections comprised the large radome, bolted to the un-numbered ring frame at the front of the forward electronics compartment, the pressurized cockpit between Frames 1 and 2, the lower electronics compartment and gun magazine between 2 and 3, the central equipment bay between 3 and 3D, Tank 1 between 3D and 4 (the front spar), Tank 2 between 4 and 5 (main spar), Tank 3 between 6 and 7, Tank 3A between 7 and 8, and the upper and lower airbrakes hinged to longitudinal beams between 9 and 10. The wings were attached to Frames 6, 6V and 7, which were machined forgings. So were 8, 9 and 10, which arched over the engines and held the vertical tails, Frame 10 also linking the spigots carrying the tailplanes.

Each wing-root rib was extended aft in a cantilever girder linking Frames 7 to 10 to carry the principal loads from the tail and the outer mountings of the adjacent engine. These girders were each 1.69m (66.5in) from the centreline. On them were mounted the fins, each canted out at 6° and with leading-edge sweep of 47°50′. Each fin comprised a base portion beginning with a sharply swept dorsal fin with vertical frames throughout, on which was added the fin proper with sweptback spars, incorporating a dielectric tip cropped at the Mach angle and a relatively small inset fully powered rudder held on three hinges. The horizontal tails had a span of 7.78m (25ft 6¼in) and leading-edge sweep of 50°. Each was powered either in unison or differentially over limits which were varied with IAS by the SOS-3M limiting signal system and ARU-29-2 load/feel system up to maximum values of +15°/–35°. Under each rear girder, close beside the engine cowl, was a typical MiG ventral fin.

Suspended under each inboard wing section was an engine inlet and duct which, because of the sharp taper in thickness of the *centroplan*, was tilted 8° outwards. This had the effect of increasing the space available between these relatively enormous engine ducts for a centreline store. The underside of each duct was straight, and exactly aligned with the longitudinal axis of the aircraft.

The inlet was generally similar to that of the MiG-25 or MiG-31, with an almost square cross-section in front view and sharp side lips swept at 60°. Boundary layer was diverted by a 100mm (3.9in) gap between the top of the inlet and the underside of the wing, this airflow being discharged through three mesh-covered rectangular apertures in the upper surface of the *centroplan*. Three hinged panels inside the roof of the duct varied throat area according to the ARV-29D control system sensitive to Mach number and air density.

A feature which was unique in the early 1970s was a system for shutting off the front of the duct to avoid FOD (foreign-object damage) when operating from contaminated front-line airstrips. Despite fitting a mudguard surrounding the rear of the nosewheels, studies showed that dangerous matter could be thrown up and sucked into the inlets. Accordingly, each inlet was provided with a shutter in the form of two light-alloy sheets joined together by a piano hinge and connected at the top by another piano hinge to the roof of the duct. Each contained 887 perforations in rectangular groups occupying the lower two-thirds of the area, but when the door was closed the engine operated normally by drawing air through five large transverse spring-loaded louvres in the top of the duct.

Starting the engines brought hydraulic pressure up to the working level, automatically rotating the doors down to close off the inlets. On take-off, the inlets were automatically opened as soon as the nose-gear leg was fully extended and airspeed exceeded 200km/h (124mph). Operation was rapid, and the pilot could not sense the inlets being opened. In flight the upper louvres could be sucked open by selecting high engine power at modest airspeeds, and in fact tests showed that 800km/h (497mph) could be sustained with the main inlets closed. On landing, as speed fell below 200km/h with the nose-landing-gear leg compressed the inlet doors would close. With the aircraft parked, loss of hydraulic pressure as the engines spooled down caused the doors to open again to facilitate inspection and maintenance.

The engine was the RD-33, specially designed for this aircraft by S P Isotov in the Klimov KB, as described in Appendix 1. Dry and afterburning ratings were 5,040kg and 8,300kg (11,110 and 18,300lb), respectively. Each engine was mounted on two keel beams (that on the outer side also carrying the tails on that side) under Frames 8, 9 and 10. Each engine and nozzle was parallel to the longitudinal axis, with a large gap between the engine centrelines.

Tank 1 had a capacity of 705 litres (155gal). The capacity of Tank 2 was 875 litres (192.5gal), Tank 3 held 1,800 litres (396gal) and Tank 3A 285 litres (62.7gal). These *centroplan* tanks were augmented by a sealed bay in each wing forming an integral tank with a capacity of 350 litres (77gal). Thus, total internal fuel capacity was 4,365 litres (960.2gal). All tanks were pressurized by bottled nitrogen or engine (fan) bleed air. The centreline attachment was plumbed for a pylon carrying an air-pressurized drop tank of circular section with a capacity of 1,500 litres (330gal). The system was fuelled via a pressure coupling in the left main landing-gear bay, but at austere forward bases gravity fuelling was possible through fillers above the *centroplan* just to the left of the fuselage spine serving Tanks 1 and 3, and through them the others.

The landing gear was designed at the MiG OKB but manufactured by Hydromash. Each main unit had a single oleo leg of high-strength steel carrying on its outer side an axle for a single wheel with a 770 × 200mm tyre, in effect a slightly enlarged 12-ply version of the MiG-25 nosewheel tyre. The leg was hinged to the wing root rib at Frame 6 and was pushed by the retraction strut directly forwards, the wheel rotating through 90° to lie horizontally above the leg in the inner wing. Separate jacks moved two bay-closure doors, one hinged under the wing outboard of the leg and the other hinged up from the side of the inlet duct and carrying an FP-8 landing light.

The nose unit had an exceedingly long leg carrying at its lower end a trailing link for hydraulically steered twin wheels with 530 × 100mm tyres (the narrowest on any MiG jet fighter). Steering limits were ±30° at speeds up to 30km/h (18.6mph) and ±8° at higher speeds. The leg was pivoted to Frame 2 and was pushed to the rear to lie in a bay closed by two doors hinged under the fuselage and three hinged to the leg. All three units had antiskid disc brakes, and the truck on the nose unit carried an FPK-250 taxi light. Track was 3.09m (121.7in) and wheelbase 5.21m (205in).

As already noted, door-type airbrakes were fitted above and below the extreme rear of the fuselage, or *centroplan*, opening to 30°. Each had a V-shaped notch cut out at the rear to leave room for the tube on the centreline housing the braking parachute. This had a cruciform canopy of 17sq m (183sq ft) area. On the tip of the nose radome was a PVD pitot probe 1.04m (41in) long, without airflow transducers, set at an angle of incidence of –6° relative to the longitudinal axis of the aircraft.

Structurally the MiG-29 was notable mainly for the dramatic increase in usage of aluminium-lithium alloys, which among other parts were used for most of the load-bearing structure of the *centroplan* and for all the skin panels of the outer wings. The latter had three forged and machined spars, joined at the root to *centroplan* Frames 6, 6V and 7. The largest single structure was Tank 3, which was automatically welded in high-strength steel forming a single unit incorporating *centroplan* spars 6, 6V and 7 and thus forming the central component to which all other parts of the aircraft were attached.

Just over 7 per cent of the airframe was made of composite materials. The flaps, ailerons, rudders and the rear portion (behind the spar) of each tailplane were made of carbon-fibre skins over a honeycomb core. The windscreen was a single polycarbonate moulding giving unobstructed and undistorted view ahead, including looking directly forwards at an angle 14° downwards. The canopy was again a single moulding in a forged frame hinged at the rear and powered upwards.

The flight controls comprised outboard ailerons, *stabilizator* tailplanes driven together for control in pitch and differentially for control in roll, and the twin rudders. The leading-edge flaps also formed part of the control system, and were electronically interlinked through the SAU-451 autopilot computer. All these surfaces were signalled mechanically, by rods and links. From the outset an objective was 'carefree' handling (i.e., with no limitations on pilot input) up to an angle of attack of 26°. As AOA neared this limit, aileron authority was progressively reduced, but the inbuilt pitch and g limiters were designed to be overridden in combat.

The secondary power systems of 901 followed previous practice. The surface power units were hydraulic, each having two actuating cylinders, one in the Main and the other in the Booster system. Both systems were energized to 210kg/sq cm (2,990lb/sq in) by separate pumps on the aircraft accessory gearbox, with accumulators holding 80 litres (17.5gal) of traditional AMG-10 mineral oil. In emergency, the Booster system could be kept operative by a pump driven by a hydraulic motor powered by the fuel on its way to the engines. The Main system also operated the flaps, leading-edge flaps, airbrakes, landing gear, nosewheel steering, engine inlets (controlled by the ARV-29D automatic control system), APU inlets and the actuators limiting stick travel and rudder deflection according to q-feel. The Booster system also drove one chamber in the stick-travel limiter.

The pneumatic system was supplied purely from storage bottles, of 18 litres (6.4cu ft) capacity, charged externally to 150kg/sq cm (2,134lb/sq in). The Main system operated the wheel brakes, deployment and release of the braking parachute, control of the cockpit canopy and driving the fuel shutoff valves. The Emergency system operated the standby extension of the landing gear and emergency wheel brakes.

The electrical system was energized by duplicated constant-speed alternators and variable-speed d.c. generators. The two GT30NZhCh12 alternators were each rated at 30kW, supplying current at 208/120V at 400Hz, driven via a GP-21 variable hydraulic drive. The GSP-ST-12/40A generators each supplied 12kW at 28.5V. They charged a 15STsS-45B battery, and PTO-1000/1500M invertors supplied single- and three-phase current at 36 and 115V. Two ground-power sockets were provided on the left side of the aircraft.

The cockpit was pressurized and air conditioned, using engine bleed air cooled in a Type 3315 liquid/air evaporator and with an ARD-57V cockpit pressure regulator. The seat was a K-36D, mounted on rails sloping back at 10°. The cockpit instruments were of the electromechanical dial type, with flight instruments fed by an SVS-II-72-3-2I air-data system, with the nose PVD boom backed up by an exceptionally long total pressure probe to the right of the windscreen, sloping down roughly parallel with the top of the nose.

Prototype 901 was not equipped with the planned avionics *kompleks* and armament systems, which will be described in connection with the various series versions. It was fitted with hardpoints for five pylons, with a drop tank on the centreline, but neither the specially designed radar nor the gun were ready in time.

On the other hand, 901 did have some parts of the OEPrNK-29 opto-electronic navigation and weapon-aiming complex. One item which in 1979 was added to 901 was the KOLS IRST (infrared search/track) and laser ranger housed under a glass ball in front of the windscreen on the starboard side, together with the OEPS-29 electro-optical sight. These units are standard on the MiG-29, and all share common optics.

The 901 prototype was constructed in the OKB prototype factory and first flown at Zhukovskiy by Fedotov on 6 October 1977. Flight testing was generally outstandingly successful but, mainly at the insistence of Menitskiy, prolonged testing was done on this and subsequent prototypes to ensure that handling was perfection, especially at extreme angles of attack and in stall/spin departures. The 901 is today on show indoors at the VVS Museum at Monino. At first called 'Ram-L' by US intelligence, this aircraft received the ASCC name 'Fulcrum'.

902 to 925

Subsequent prototypes funded on the original contract differed only in minor respects from 901, except for a redesign of the nose landing-gear unit. Despite the large mudguard and the inlet shut-off doors, the twin nosewheels still caused problems with FOD (water and sand, for example) and the answer was to move the nosewheels aft, even though this increased 'nodding' when taxiing. The new leg had similar geometry but was shorter, and moved back from Frame 2 to Frame 3, behind the upper lips of the inlets. The unit was simplified, the mudguard being replaced by a light scraper, and the three portions of door being removed and the retraction bay sealed by intermeshing left and right doors hinged to the fuselage. Despite the need to make the retraction bays larger, the sizes of all three tyres was significantly increased. The nosewheels were fitted with 570 × 140mm tyres, and the mainwheels with 840 × 290mm tyres, the same Type 2A tubeless tyre as fitted to the MiG-23 family. The larger tyres became standard.

The prolonged exploration of handling resulted in repeated often minor changes to the flight-control system. The ventral keels (underfins), which had been intended to improve stall recovery, were eventually found to have little effect, and to save weight were omitted from most of the prototypes. They were exhaustively evaluated with 917, which also explored rudders of increased chord, first tested on earlier aircraft, projecting behind the trailing edges of the fin. The two outer sections of leading-edge flap were made into one, for a total of four on each wing, and the inner and outer sections of the flaps and ailerons were likewise made as one unit.

All subsequent single-seaters were fitted with a remarkable new gun, though it was not designed specially for the MiG-29. As outlined in Appendix 2, the GSh-30/I (Type 9A4071) is a single-barrel 30mm weapon claimed to be lighter than any other gun of this calibre. It is installed alongside the fuselage in the extreme front left tip of the *centroplan*, fed by a box magazine accommodating up to 159 rounds of linked ammunition (150 is usual). The gun is controlled electrically, has internal water cooling, and the bay is cooled and purged of gas by an extractor aperture energized by muzzle blast. Chutes discharge links and cases overboard down the space between the powerplants.

Single-seaters were also fitted with provision for three pylons under each wing. Details of weapon loads and avionics are given for each type of series aircraft.

The thirteen prototypes which followed 901 were used for various different purposes:

902 First flown in November 1979, this was used for OEPrNK-29 tests. It was the first prototype to be fitted with the definitive secondary power system. While leaving a mass of engine accessories on top of each engine fan case, both engines also had a shaft drive to a KSA-2 aircraft accessory gearbox on the centreline in a fireproof bay ahead of Frame 8. Attached to the same gearbox is a GTDE-117 gas-turbine APU (auxiliary power unit). Rated at 73kW (98 shp), this can be kept running when a combat mission is imminent, providing a shaft-drive to both engines for a rapid start to self-sustaining speed. The APU also provides emergency secondary power following double engine failure. It is fed via a ram inlet on the left side of the spine and exhausts under the fuselage. If a centreline tank is fitted the APU exhaust is ducted through it via a heat-insulated pipe.

903 As it was assigned to engine development, and did not have the complete OEPrNK-29 system, this aircraft flew before 902, in June 1978. At the very start of testing, on 15 June, catastrophic failure of one engine caused a severe titanium fire which forced Menitskiy to eject.

904 This aircraft was assigned to inflight analysis of structural loads, which also involved establishing the practical limits of combat manoeuvres. When this programme was completed, 904 was presented for LII testing.

908 This was added to the prototype programme as a replacement for 903 to test the RD-33 engine. It was flown in 1979, and suffered uncontained engine failure on 31 October 1980, Fedotov ejecting.

917 This, the sixth flight article, was intended to be the *Etalon* (standard) for production, a role actually fulfilled by 925. First flown in November 1980, it was used in NII-VVS State tests. As noted earlier, it investigated tail configurations, and it also cleared for use the overwing chaff/flare dispensers ahead of the fins.

918 This was the first MiG-29 to be fitted with radar. Developed by the bureau later privatized as Fazotron, the N019 is also known as RLPK-29 (S-29). Brief details are given in the description of the MiG-29.

919, 920 These aircraft were assigned to weapon-system tests and trials with operational equipment.

921 First flight August 1981. Testbed for the RD-33 and RD-33K.

922 Unlike most other prototypes this aircraft was not submitted to State testing but, after four flights, was sent to CAHI (TsAGI).

923 First flight November 1981. NII-VVS testbed for OEPrNK-29 and KOLS.

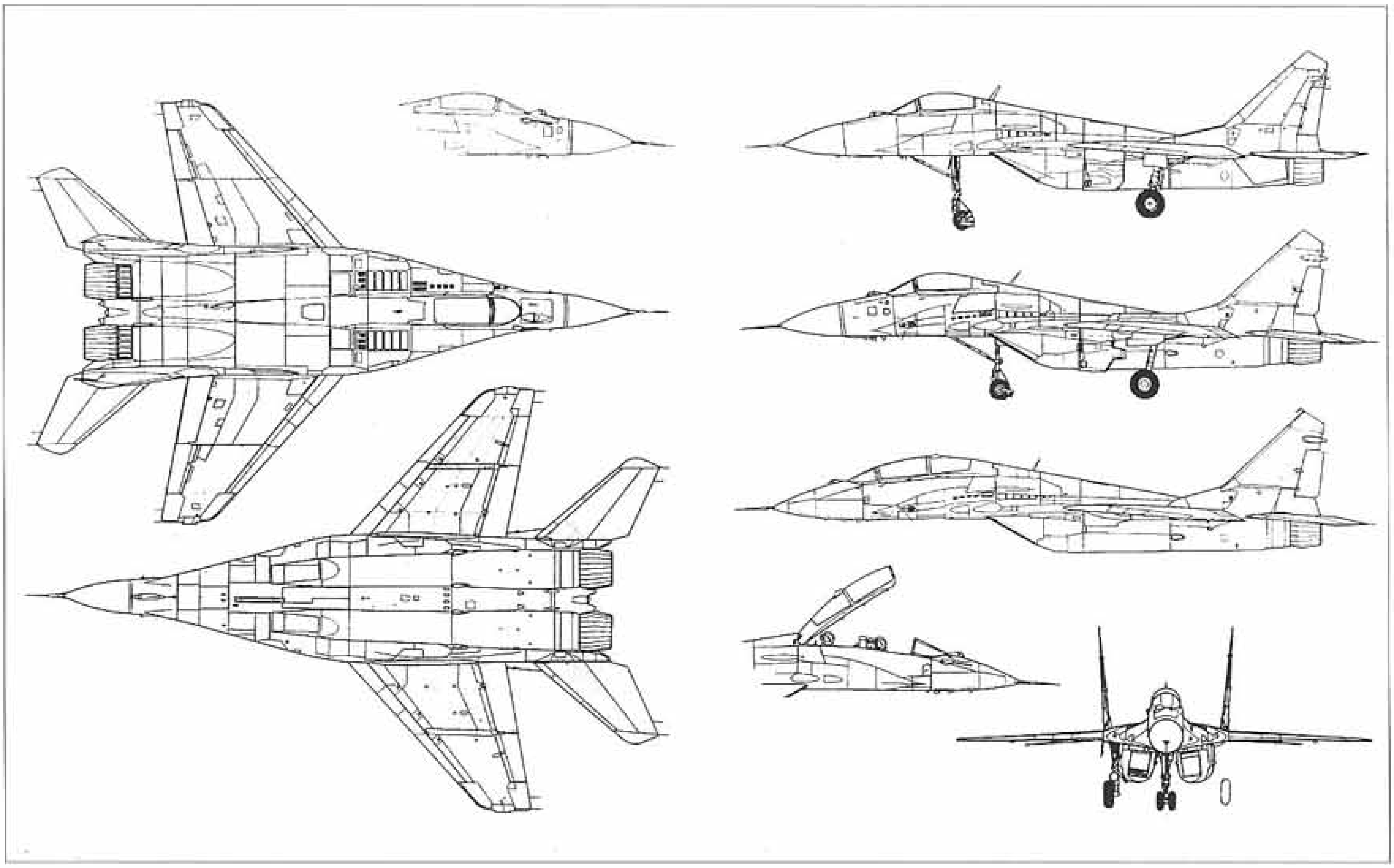
924 Submitted for testing to LII.

925 First flight December 1982. Final prototype and *Etalon* for production fighter. Used for State tests.

MiG-29, 9-12, *Izdeliye* 5

The initial production standard was for a single-seat counter-air fighter, with visual ground-attack capability. It was also required to have reconnaissance capability, and though this could be provided by attaching MiG-21R type sensor pods this has not so far been requested by a customer. Design load factor in symmetric flight is 9g.

Internal armament comprises the GSh-30/I gun, already described. External stores can be loaded on six underwing pylons, the centreline attachment being reserved for a 1,500lit (330gal) tank. Maximum weapon load is 3,000kg (6,614lb). Each inboard and middle pylon can be fitted with an APU-27 launcher for an R-27R1 medium-range AAM (air-to-air missile). Alternatively they can be fitted with an APU-73-1D launcher for an R-73E short-range AAM, or a B-8M1 20-tube pod for S-8 rockets, or an APU-68-85E launcher for single S-24B 240mm rockets, or a KMGU-2 container for VKF bomblets, or a BDZ-UMK2B universal rack or MBDZ-UT2-1 multishackle rack for a wide range of free-fall stores up to 500kg (1,102lb) size. Common loads include FAB-250 and FAB-500 bombs and ZAB-500 napalm, but tactical nuclear weapons are prohibited by the CFE treaty. The outer pylons carry APU-73-1D launchers only, for R-73E missiles. Though no longer standard, when originally delivered many aircraft had the middle and outer pylons interfaced for R-60 or R-60M short-range AAMs. Pylon status, weapon selection



MiG-29 (9-12) with starboard engine inlet closed in front view; top side view, 901 prototype; bottom side view and lower inset, 9-51 MiG-29UB; upper inset, right-side of MiG-29 nose.

First production MiG-29. (OKB)

and launch are handled by the SUO-29M armament control system.

During the course of production several significant modifications were introduced. One that was made retroactively to aircraft already delivered was to add a small sharp-edged triangular fairing on each side of the PVD boom to generate spiralling vortex wakes which enable lateral control to be maintained to angles of attack beyond the original limit of 26°. First tested on prototype 917, another addition which became standard was to install a BVP-30-26M payload dispenser ahead of each dorsal fin. Each dispenser is secured by removable screws to fire vertically under control of an SUVP-29 passive jamming control subsystem. Its capacity is thirty PPI-26-1B chaff or flare cartridges of 26mm diameter.

The main radar of the MiG-29 is the RP-29 or S-29, also designated N019, developed by Fazotron, forming the main element in the RLPK-29 radar-aiming *kompleks*. Later production aircraft have the RP-29E (E for export). Together with the Ts100.02.06 digital computer, this forms the RLPK-29E radar-aiming *kompleks*.

The S-29 is a typical pulse-doppler set of the 1970s, without any ground-mapping modes but able to track ten aerial targets simultaneously and guide semiactive missiles. It has a twisted-Cassegrain antenna, scanned mechanically over limits of ±67° in azimuth, and +60°/–38° vertically. Fazotron describe the detection range against fighter-type targets as 100km (62 miles), but pilots of customer air forces have often said the achieved range can be much greater. Tracking range is officially 70km (43 miles). Later MiG-29 variants have radars of greater power, matched to longer-ranged R-27 missiles.

The axis of the radar antenna is normally collimated (boresighted) parallel to that of the KOLS IRST and laser ranger described previously. Thus, the SEI-31 (SEI-31-E2 for export) integrated display in the top right of the cockpit panel can combine radar information with that from the opto-electronic system. The OEPrNK-29 (-E2 added to the designation for export) opto-electronic *kompleks* comprises the IRST and laser ranger, plus the SN-29 navigation system. Major elements of the SN-29 are the A-323 RSBN short-range (Tacan-type) radio navigation system and (ILS-type) bad-weather landing system, the Ts-050 directional/vertical gyro AHRS (attitude/heading reference system), the SVS-II-72-3-2I air-data system (with embedded computer) and the BK-55 switching unit. The air-data system is fed from the nose probe, a DUA-3M vane on the left side of the nose to sense angle of attack and total-temperature tubes on the left of the cockpit and (paired) on the outer side of the left fin.

Position error with no input from ground stations is up to 8km (5 miles) per hour of flight, wander off track is not greater than 0.5° per hour, and pitch/roll error is again within 0.5° per hour. On a bad-weather landing approach guidance is available down to 50m (164ft) without ground assistance.

The aircraft digital computer (unrelated to that in the radar *kompleks*) is the TsVM 100.02.02. The radio compass is an ARK-19, with a directional antenna under a dielectric square in the top of the fuselage spine and an omnidirectional mast antenna sloping back on the centreline immediately behind the canopy. The marker receiver is a type A-611, with its rod antenna pointing forwards under the rear of the nose radome. Slightly further back are the transmitting and (further back again) receiving antennas of the A-037 radar altimeter.

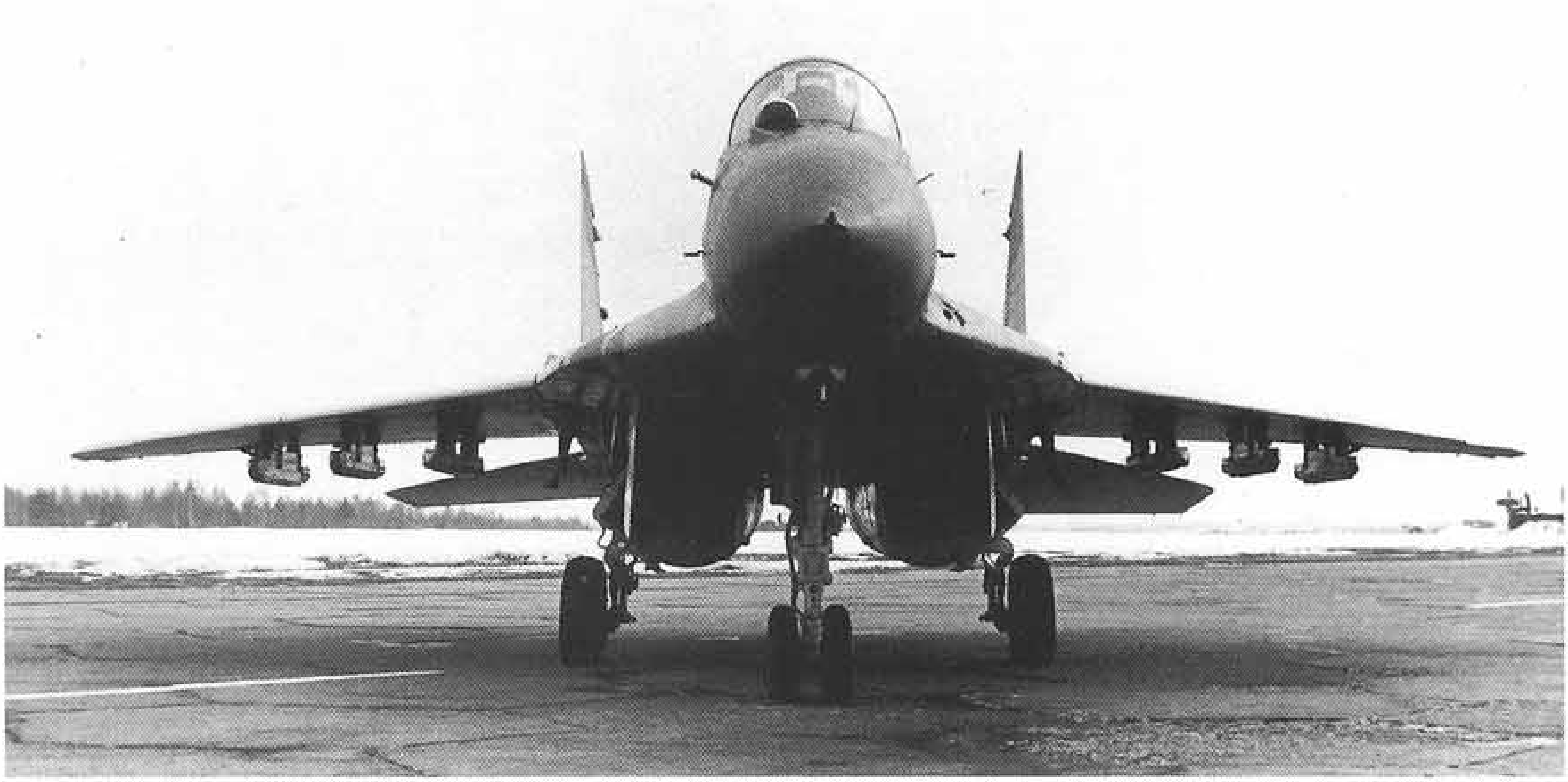
The short-wave (uhf) radio is the R-862, with its antenna inside the cap of the starboard fin tip. The aircraft transponder for air-traffic control is the usual SO-69 (K-42, or K-42E for export), with antennas in each *centroplan* leading edge. Adjacent to these antennas are the forward-hemisphere receiving antennas for the SRO-2 radar transponder Band I (port and starboard leading edges), the aft hemisphere being covered by an aft-facing antenna near the top of the port fin. The SRO-2 Band-II antennas are inside the starboard fin cap and in the trailing edge of the port fin, with azimuth coverage overlapping with antennas inside both wingtips. The SRO-2 Band III antennas are a blade under the nose and inside the port fin cap.

Above the nose are the triple rods of the associated SRZ-15 radar interrogator. The *Pion* (peony) antenna feeder system uses 'bow and arrow' antennas under the nose and facing aft from the top of the starboard fin. The ground command radio link is the E502-20, with its antenna inside the port fin cap. The radar-warning system was originally *Sirena*-3M, but this was soon replaced by L006LM, with wide-angle receiver antennas in the extreme front of the *centroplan* on both sides and in the surface of both wingtips.

The SAU-451 three-axis autopilot has a disengagement button on the stick. It is backed up by the ARU-29-2 q-feel system, and protection against stall/spin departures is provided by the SOS-3M, limiting angle of attack to 22° in the first series aircraft, later raised to 24° (over-rideable in combat). Other equipment includes the *Almaz*-UP (diamond) cockpit voice recorder, a *Tester*-UZLK flight-data recorder, an *Ekran*-03M (screen) BITE (built-in test equipment) and warning installation and VSS-1-4K cockpit lighting control. The pilot's helmet incorporates the *Shchel'*-3UM-1 (*shchel'*, a chink or crack) independent designation system (helmet-mounted sight) for cueing missiles on to off-boresight targets in close combat.

About 600 MiG-29s were constructed at the Moscow *Znamya Truda* factory and at Gor'kiy in 1982–91, alongside the MiG-29S from 1985. The first regiments received aircraft in June 1983, by which time the OKB had made over 2,000 test flights with proto-

MiG-29, 9-12. (photograph by Yefim Gordon)



MiG-29, 9-12. (photograph by Yefim Gordon)

types. The MiG-29 was designated 9-12 for the Soviet Union, 9–12A for Warsaw Pact air forces and 9–12B for export customers. Past and present customers comprise Afghanistan, Belarus, Bulgaria, Croatia, Cuba, Czechoslovakia and Czech Republic, the German Democratic Republic, Germany, Hungary, India, Iran (with locally installed inflight refuelling), Iraq, Kazakhstan, North Korea, Moldova, Poland, Romania, Slovakia, Syria, Turkmenistan, Ukraine, Uzbekistan, Yemen and Yugoslavia. Moldova sold a batch to Yemen and 21 (for $40 million, with 500 missiles) to the USAF. Belarus sold a batch to Peru. The ASCC name is 'Fulcrum-A'.

Span 11.36m (37ft 7¼in); length 17.32m (56ft 10in), (excluding PVD) 16.28m (53ft 5in), (fuselage) 14.72m (48ft 3⅝in); wing area (net) 38.0sq m (409sq ft), (gross) 43.5sq m (468sq ft).

Weight empty (equipped, operating) 10,900kg (24,030lb); internal fuel 3,623kg (7,987lb); loaded (clean) 14,670kg (32,341lb), (maximum) 18,480kg (40,741lb).

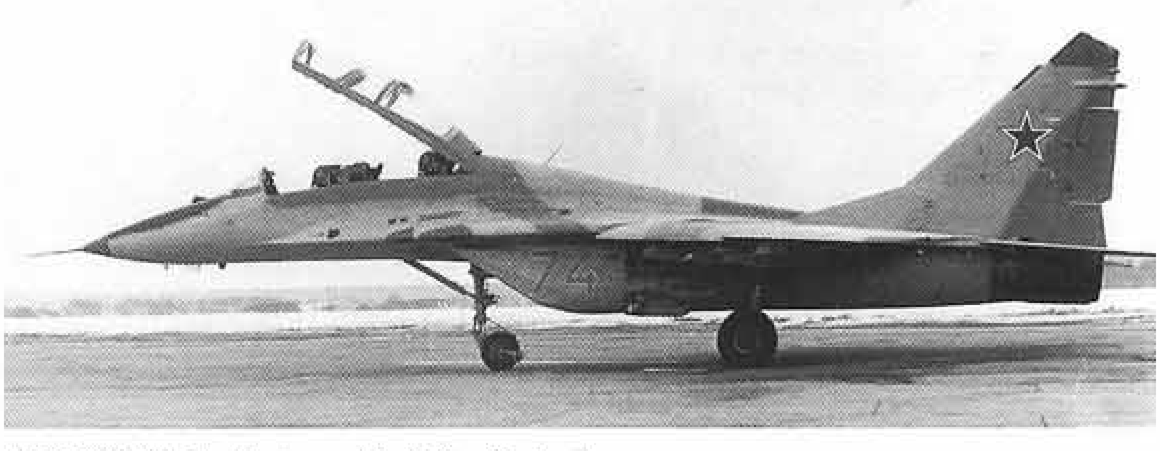
Maximum speed at sea level 1,250km/h (777mph, Mach 1.02), at high altitude Mach 2.35, equivalent to 2,500km/h (1,553mph); limiting IAS 1,500km/h (932mph, 809.5kt); acceleration at low level (600 to 1,100km/h) 13.5sec; initial climb 330m/s (64,960ft/min); climb to 6,000m (19,685ft) 55sec, service ceiling 17,900m (58,730ft); range (clean) 1,500km (932 miles), (centreline tank) 2,100km (1,305 miles); takeoff speed 270km/h (168mph); takeoff run 260m (853ft), (dry power) 650m (2,133ft); landing speed 235km/h (146mph); landing run 600–700m (1,970–2,300ft), (without drag chute) 950m (3,120ft); limit load factor +9/–5.

MiG-29UB, 9-51, *Izdeliye* 30

Mikoyan planned several two-seat versions, but the first variant to follow the basic MiG-29 was the MiG-29UB (*uchebnyi boyevoy*, trainer for combat). Virtually all the differences are confined in the forward fuselage. The pupil's cockpit, almost identical to the original, is in front at a significantly lower level. The front windscreen is the same as for the MiG-29, and both cockpits are covered by a one-piece canopy hinged at the rear and powered up by a pneumatic ram. Both occupants have K-36DM seats; the instructor can eject the pupil but cannot disconnect his flight controls.

By removing the radar it was possible to hold the length of the fuselage within 100mm (under 4in) of the single-seater. All other sensors and weapons are fitted, and the pupil can practice simulated interceptions with the gun (usually 50 rounds only) and missiles (normal stores limit, 2,300kg, 5,071lb). Both occupants have rear-view mirrors, those for the instructor being around a transverse frame around the canopy. In the top of the same frame is a folding wide-screen periscope, extended by lowering the landing gear, which improves the instructor's view ahead. Special equipment in the instructor's cockpit can simulate target information on the pupil's HUD sight or any of a range of inflight emergencies. An SPU-9 intercom is fitted.

The prototype was first flown by OKB pilot A G Fastovets on 29 April 1981. The series MiG-29UB was built only at Gor'kiy (the *Sokol* factory, now MAPO Nizhniy-Novgorod). All customers for the single-seater purchased a number, the total number built in 1985–91 being 197. Two, locally called MiG-29NUB, with Western avionics, were bought by Malaysia. The ASCC name is 'Fulcrum-B'.



MiG-29UB, 9-51. (photograph by Yefim Gordon)

MiG-29UB, 9-51. (photograph by Yefim Gordon)

Dimensions as for MiG-29 except length 17.42m (57ft 1⅞in).

Weight empty (equipped, operating) 10,880kg (23,986lb); internal fuel 3,623kg (7,987lb); weight loaded (clean) 15,000kg (33,070lb), (maximum) 18,000kg (39,683lb).

Maximum speed (sea level) 1,350km/h (839mph, Mach 1.14), (high altitude) 2,400km/h (1,491mph, Mach 2.26). Other data similar to MiG-29.

MiG-29, 9-13, *Izdeliye 7*

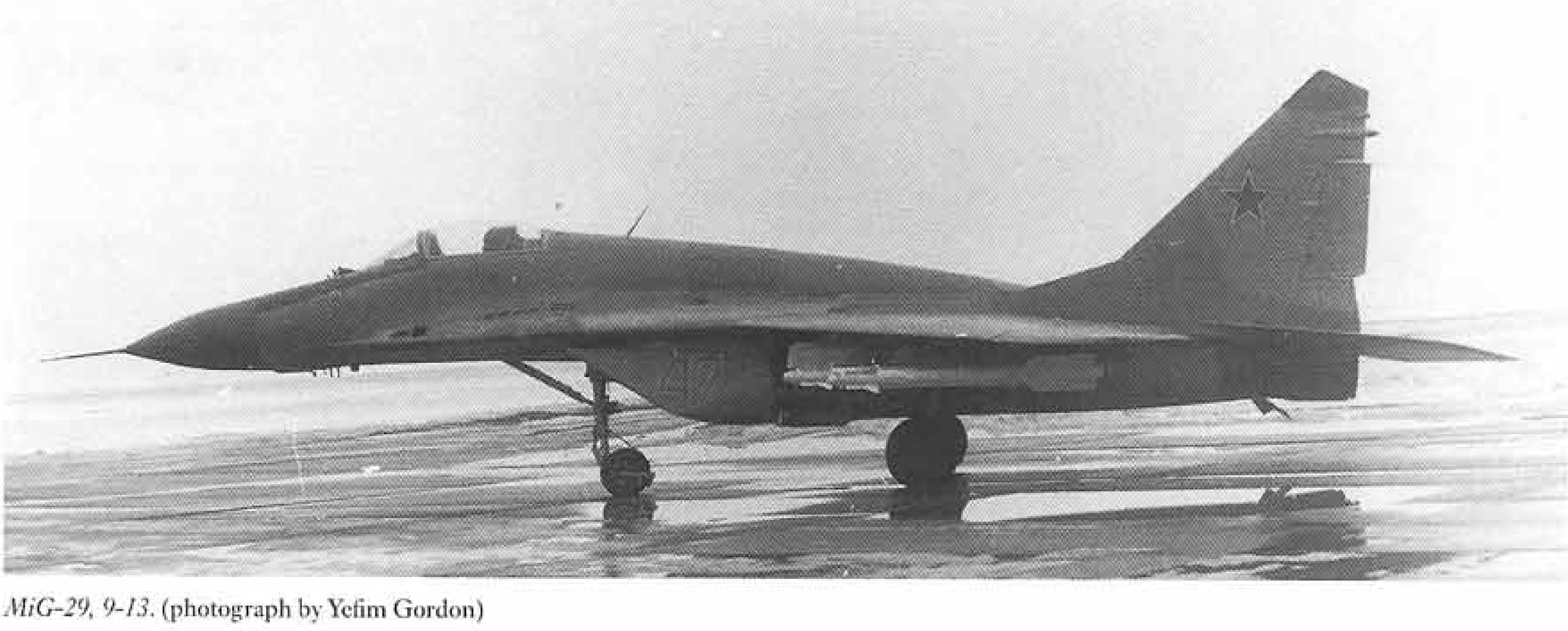
With this designation a number of MiG-29s were produced in 1982–91 with a slightly enlarged dorsal spine. This provided an increased internal fuel capacity, as well as room for the *Gardeniya* (gardenia) ECM installation. This modification is discussed later in the MiG-29S versions of 9-13.

MiG-29S

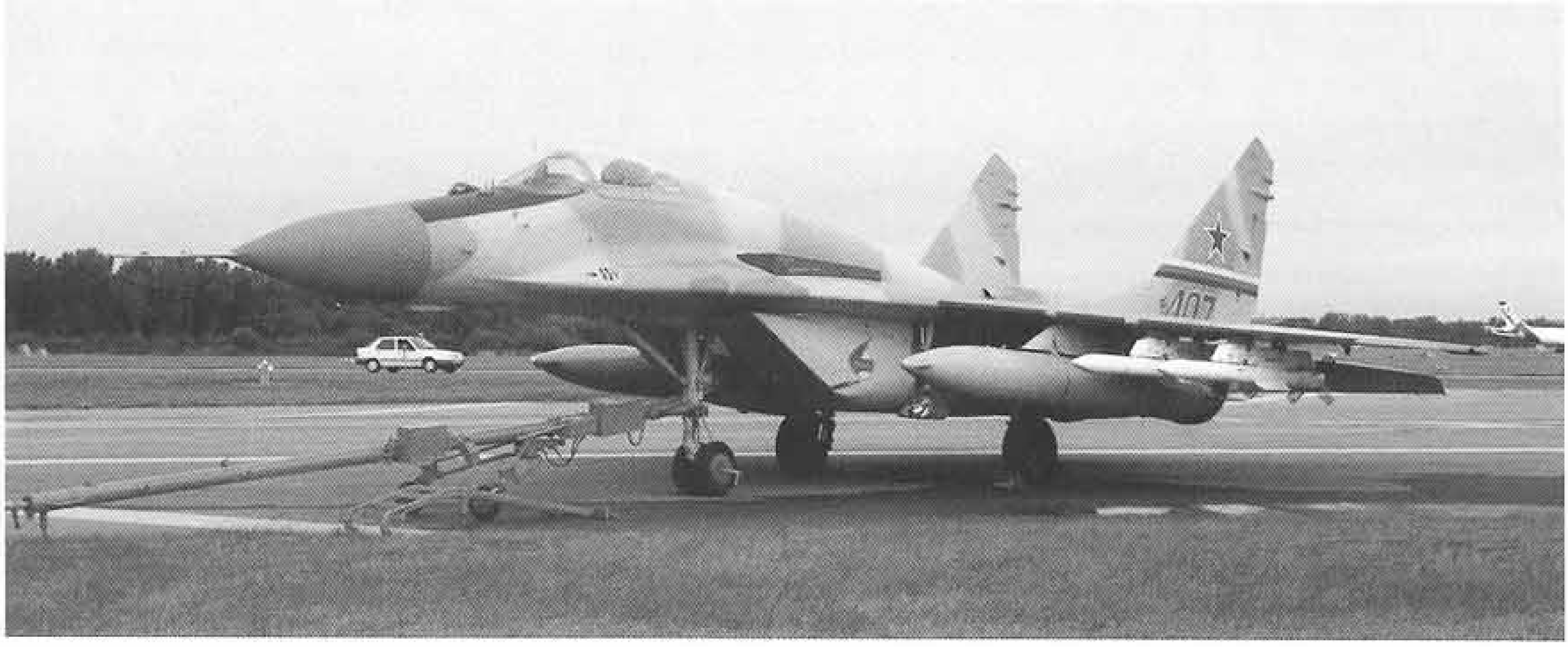
As the first upgrade, this basic designation covers six distinct production versions. These are: the MiG-29S, 9-12S; the MiG-29SD, 9-12SD; the MiG-29SE, 9-12SE; the MiG-29S, 9-13S; the MiG-29SE, 9-13SE; and the MiG-29SM, 9-12SM. All versions have the inboard underwing pylons plumbed for 800lit (176gal) or 1,150lit (253gal) drop tanks. The 9-12 versions (except in the first examples) also have fuselage Tank 1 increased in capacity to 780 litres (171.6gal). The 9-13 versions have a bulged spine and still greater capacity.

MiG-29S, 9-12S

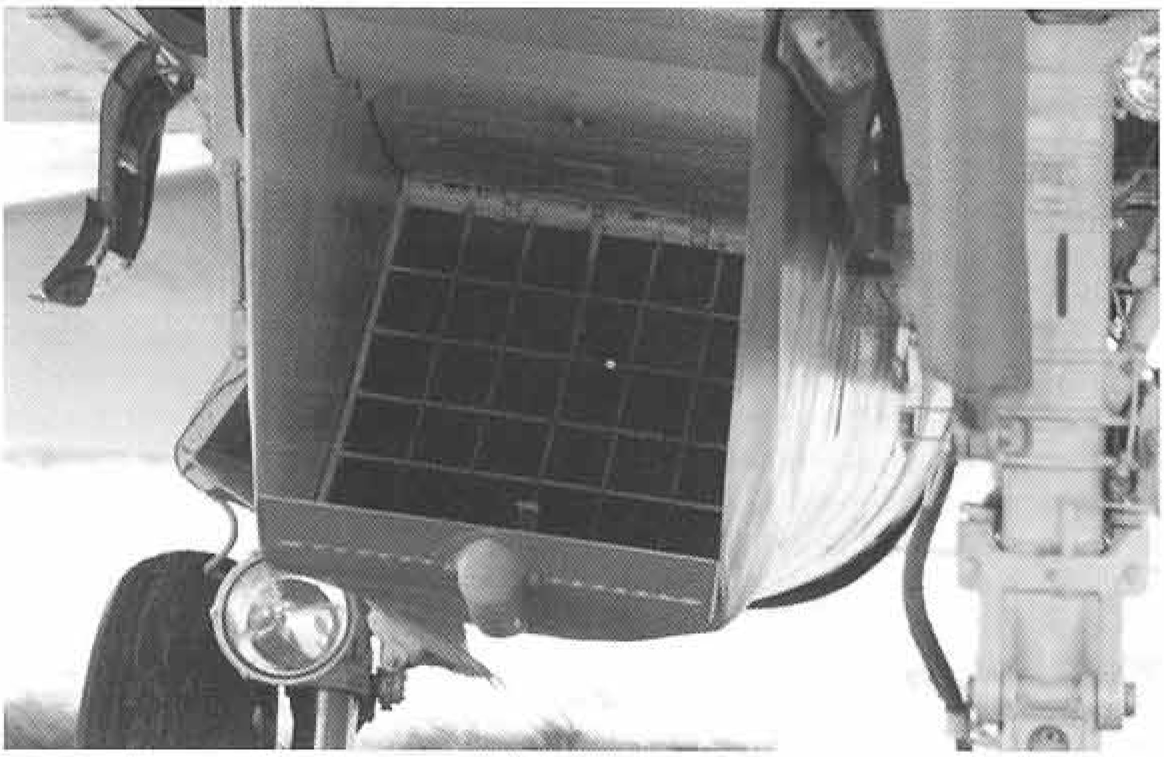
In 1985 an employee of Fazotron, Aleksandr Tolkachev, was arrested after he had handed to a Western agent technical documents describing the radars and other avionics of the MiG-23M, MiG-29, MiG-31 and A-50. It was accordingly decided that these aircraft had to be fitted with different (if possible upgraded) radars and IFF systems. The OKB was given an immediate contract for the MiG-29S, 9-12S.



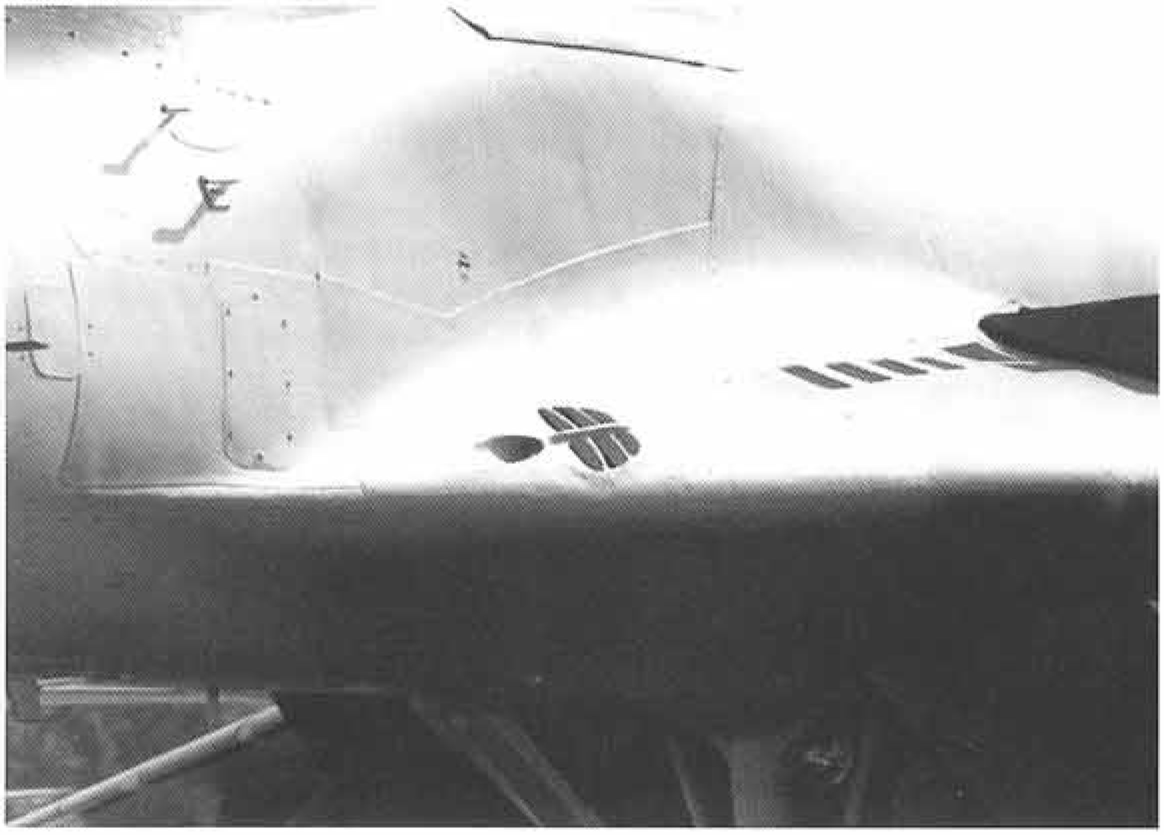
MiG-29, 9-13. (photograph by Yefim Gordon)



MiG-29S. (RART)



MiG-29S inlet. (RART)



MiG-29S gun. (RART)

Accordingly, this version, for Soviet Union and Warsaw Pact customers only, was fitted with the RLPK-29M radar-aiming *kompleks*, incorporating the N019M *Topaz* radar. Unlike the N019, this has a mechanically scanned slotted flat-plate antenna, and can engage two aerial targets simultaneously. Against fighter-type targets Fazotron quote an effective tracking range of 75km (47 miles) with a sky background, or 65km (40 miles) against the ground, or 35km (22 miles) against a low-level target from astern. This radar also offers a ground-mapping mode, and is compatible with all MiG-29 missiles, including the R-27T1, RE1 and TE1 which cannot be fired by the MiG-29. It is also compatible with the R-77 (RVV-AE), which has its own active seeker. The digital computer in the radar-aiming *kompleks* is the Ts101M, with enhanced memory and improved software to counter hostile jamming.

Equally important upgrades concerned the flight controls and avionics. The autopilot is upgraded to the SAU-451-04 or -6, and the limiting signal system is upgraded to the SOS-3M-3, with the actuation trigger postponed to an AOA of 28°. Both autopilots introduced hydraulic actuators added to the aileron power units to impose progressive limitation of surface deflection at extreme AOA beyond 26°. The 451-05 additionally enables rudder deflection to be progressively increased, to maintain yaw control at similar AOA. The SOS-3M-3 triggers an audio warning at AOA beyond 26°.

Maximum weapon load is increased to 4,000kg (8,818lb), for example by fitting interfaces for tandem pairs of FAB-500 bombs on each middle and inboard pylon. Another possible load comprises two FAB-500 on each inboard pylon, a single FAB-500 on each middle pylon and R-73E missiles on the outers. From 1998 the R-73M should be available. Combinations in the counter-air role include six R-77 missiles, or four R-77s and a pair of R-27s (any version) on the inner pylons. A new load against ground targets is a B-13 launcher on each middle and inner pylon, each firing five S-13T or S-13OF heavy rockets of 122mm calibre. A further option is firing the gun with the centreline tank installed, which previously was prohibited because the tank could be damaged by spent cases.

The IFF system is upgraded. The radar interrogator is the 6231R or S35MR (035MR), whose newer microelectronic construction offers higher reliability. This unit operates jointly with the new 6201R radar transponder, covering Bands I, II, III and VII, and also with ATC transponder SO-69M *lit.*K11E, which is compatible with Western ground environments and can be used as the interrogator in place of the 6231R. Antenna locations are unchanged. ASCC name unchanged.

Dimensions as MiG-29.

MiG-29SD, 9-12SD

This export version combines the original airframe with the slightly downgraded RLPK-29ME radar-aiming system, incorporating the N-019ME radar, and the OEPrNK-29-1E optoelectronic system. Equipment includes an SAU-451-06 autopilot, STR6-5A fuel-management system and, as customer options, TNL-1000 GPS navigation, ARN-118(V) Tacan, ILS-71 ILS, a second R-800L1 radio with 243Hz emergency channel, and an FKP-EU film camera looking through the HUD sight.

MiG-29SE, 9-12SE

This export version generally resembles the 9-12SD, with the same avionics, but has a customer option of inflight refuelling, with a retractable probe and with fuel management by the STR6-5 system. The Royal Malaysian Air Force selected this option in its variant locally called MiG-29N, with ARN-139 Tacan, GPS, and US-supplied ILS and IFF. Priced at $560 million, this contract for 18 aircraft (from Series 52 and 53) was a godsend, enabling the OKB to complete several development programmes, and also funding production of the R-77 missile. The aircraft were delivered in 1995–96. In October 1997 a $34,440,000 contract was signed to double the external weapon load from 2,000 to 4,000kg, fit the FR probe and add the R-77 missile. The RMAF is negotiating for a further 18 aircraft.

In November 1997 Ecuador, concerned at the sale to Peru, signed for 12 aircraft. These comprise ten of the 9-12SD or SE and two 9-51 trainers.

MiG-29S, 9-13S

Rearrangement of avionics and redesign of the spine, so that its top is not straight in side elevation but slightly bulged, enabled capacity of Tank 1 to be increased to 890 litres (196gal). The fuel management and indicating system is upgraded from STR6-2A to STR6-5A.

The opto-electronic *kompleks* is the OEPrNK-29–1E, incorporating the Ts100.02.07 digital computer, SYeI-31-1E integrated display and SUO-29M4 armament control system. All 9-13 aircraft have the option of the L203BE *Gardeniya* (gardenia) internal jamming system. Hostile signals are received by flush spiral disc antennas in the outer side of each dorsal fin and by wide-angle azimuth antennas on each fin near the top of the rudder. The transmitting antennas are in the wingtips. Control is achieved by adding unit L138 to the L006LM warning system, which determines threat direction and, if necessary, fires appropriate flare cartridges.

Other new equipment includes an upgraded environmental system (with a 3268 fuel/air heat exchanger, 3314 equipment-compartment cold-air unit, 6377 dehumidifier and 6635-2 cockpit pressure regulator), the *Ekran*-13ME BITE/warning system, a KSA-3 aircraft accessory gearbox with a PGL-40 constant-speed drive for each alternator (with modifications to the electrical system), and two FP-15 landing lights.

The 9-13 prototype, 'Blue 407', was first flown on 23 December 1980, by V M Gorbunov. This and some other development aircraft had five sections of leading-edge flap, but the production aircraft have three sections. All aircraft of the 9-12 and 9-13 families can be retrofitted with RD-33 Series 2 engines, or with the RD-133 with 3-D thrust vectoring, or with an inflight-refuelling probe, or various upgraded avionics. The ASCC name for all 9-13 bulged-spine versions is 'Fulcrum-C'. Data are for a typical 9-13 MiG-29S.

Dimensions as MiG-29.

Weight empty (equipped, operating) 11,200kg (24,691lb); internal fuel 6,670kg (14,705lb); loaded (clean) 15,600kg (34,391lb); maximum takeoff weight 20,000kg (44,092lb).

Performance as MiG-29 except range (clean) 1,700km (1,056 miles), (three tanks) 3,000km (1,864 miles).

MiG-29SE, 9-13SE

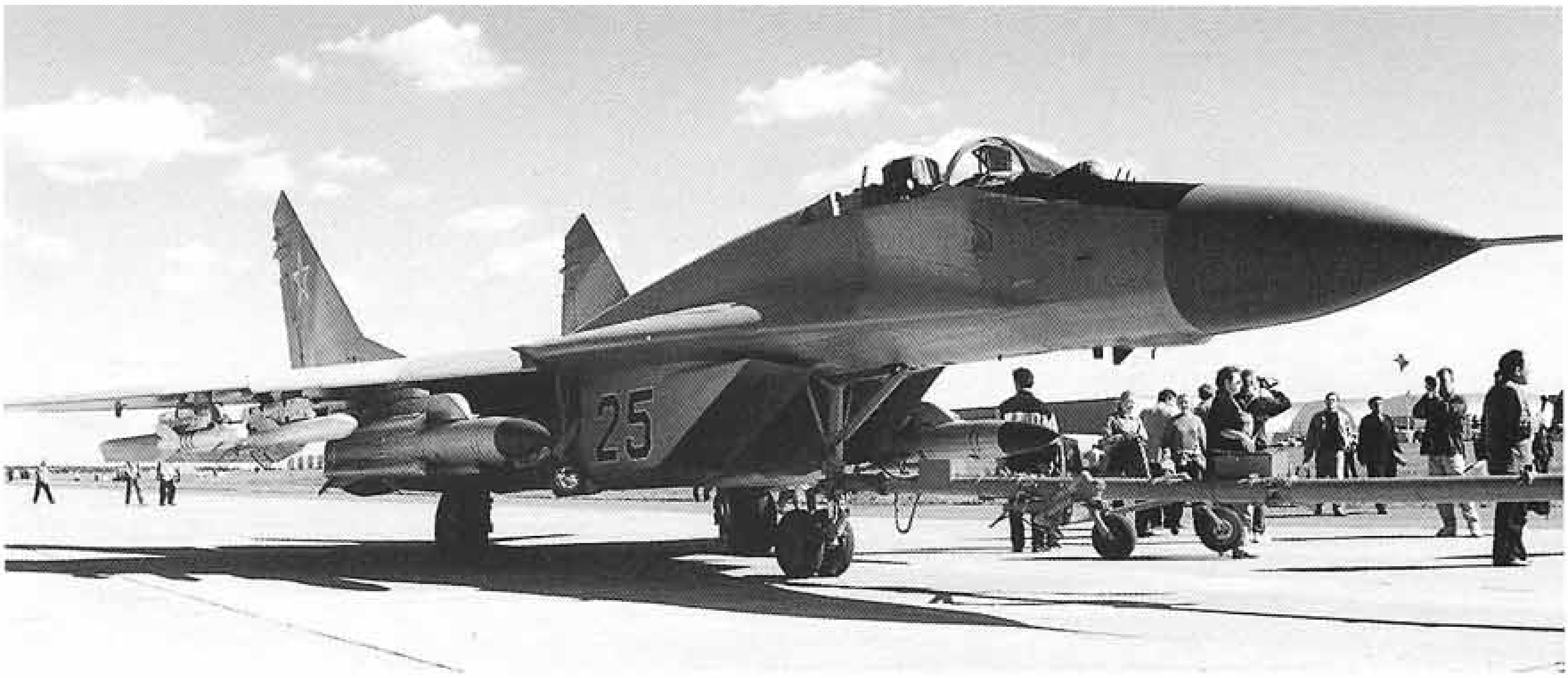
This export version combines the downgraded RLPK-29ME with the unchanged OEPrNK-29-1E and the enhanced fuel capacity and bulged spine. Unlike MiG-29SD versions, this SE has virtually all the upgrades of the Russian-operated MiG-29S, including the new environmental system and the L203BE internal jammer.

MiG-29SM, 9-13SM

This version, produced only for Soviet Union and Warsaw Pact customers, is fitted with pylon interfaces and additional avionics, including the required cockpit TV display, to enable it to launch and guide two Kh-29T or Kh-29TE missiles or four KAB-500KR bombs with TV guidance. The prototype, C/n 17941, was first flown in 1995. A small number have been built, or upgraded from earlier versions, and in 1996 the demonstrator was certified to launch the Kh-31A antiship missile and the Kh-31P antiradar missile. These missiles have range greater than the effective range of the N019M radar, and are better matched to the N010 of the MiG-29M. Data essentially as for 9-13.

MiG-29SMT, 9-17

At the Paris airshow in June 1997 MAPO-MiG revealed an extensive midlife upgrade available for aircraft of the above types. The most extensive modification is to increase internal fuel capacity by 960kg (2,116lb), or about 1,182 litres (260gal), by eliminating the auxiliary inlet system in the *centroplan* (as in the MiG-29M, described later) and adding a conformal large spine as on the 9-13.



MiG-29SMT at the MAKS-97 airshow. (photograph by Yefim Gordon)

Further elements in the upgrade are avionic. The cockpit instrument panel is replaced by a new one with two large multifunction colour displays, each 18cm high by 15cm wide (7 × 6in), together with two smaller displays plus standby miniature instruments in the centre. Most information can be displayed on either main screen, but only the right display can show TV pictures relayed from the cameras of smart bombs and TV-guided missiles. A further upgrade is to add a ground-mapping mode to the N019M *Topaz* radar, with resolution better than 15m (49ft).

The new digital avionics are linked into an STD-1553B bus, together with improved HOTAS (hands on throttle and stick) controls. Provision is made for the complete spectrum of MiG-29M weapons, and for an FR probe. The interim SMT prototype began its flight-test programme from Zhukovskiy on 29 November 1997. At the 1998 Farnborough airshow this aircraft is expected to appear powered by RD-133 engines with 3-D vectoring nozzles, which may already have begun flying in an *ad hoc* testbed (*see* 9-15 above). The SMT features will probably be added to the 9-15 MiG-29M to create the next-generation MiG-33, a designation already mentioned in connection with the earlier MiG-29ME.

Dimensions as MiG-29M.

Weight loaded 16,000kg (37,273lb); maximum loaded weight 21,000kg (46,297lb).

Performance as MiG-29M except initial climb 330m (1,083ft)/s (19,800m, [64,961ft]/min); range without flight refuelling 3,500km (2,175 miles).

MiG-29M, 9-15, *Izdeliye* 9

Though the MiG-29 appeared impressive when it was first seen 'in the flesh' in Finland in 1986, it was then already a ten-year-old design. At that time the Mikoyan team had already flown the first prototype of the second updated version, which is a much greater advance than the MiG-29S. This began by introducing a new radar and avionics suite, uprated engine, 'glass' cockpit and, most important of all, a redesigned FBW (fly-by-wire) flight-control system. What was not expected at the outset was that the airframe would also be largely redesigned to reduce weight, greatly increase internal fuel capacity (without increasing external bulk) and improve serviceability and design structural life.

Dealing with the airframe first, the external appearance changed only in subtle ways. The wings retain the original aerofoil profile but the leading-edge flap is divided into only two sections, the trailing-edge flap angles were changed to 25° for takeoff and 29° for landing, and the ailerons were extended to meet the bulged wingtips. Moving in to the *centroplan*, this now has a sharp leading edge – the chief recognition feature – which generates favourable vortices at high angles of attack and helps to reduce radar cross-section to one-twelfth that of a MiG-29S.

The radome now has a less bulged aerodynamic profile. The cockpit has been moved upwards and the K-36DM seat slightly forwards, giving a 15° view over the nose. This required a canopy that is longer and 40mm (1.6in) higher. Behind the canopy the spine is not bulged as in the MiG-29S but straight; but it is broader and more capacious, tapering at the rear into a broad 'beaver tail' extending behind the engine nozzles. The trailing edge of each lower fin is now vertical and aligned with that of the extended-chord rudder. Not least of the visible changes, the chord of the tailplanes is increased by more than 50 per cent, especially outboard of a dogtooth halfway along the leading edge similar to that of the MiG-29K.

A single large (1.2sq m, 12.9sq ft) airbrake hinges upwards from Frame 8, replacing the two previously used. The engine air inlets are increased in capture area, fitted with hinged lower lips driven by a hydraulic actuator faired underneath, and fitted with simple protective screens instead of shut-off doors. Each screen is a 6 × 6 grille of thin crossing members offering little resistance to the airflow. It lies diagonally across the duct until after takeoff, when it swings up to lie flush in the roof behind the variable throat panels. The grilles, which are protected against icing, offer little obstruction to slush and stones, but prevent a whole bird from reaching an engine.

Eliminating the shut-off doors not only saves weight but also enables the row of auxiliary inlets above the duct to be dispensed with. This has saved further weight and complexity, and, together with a reduction in size of the gun magazine, enables the entire *centroplan* between Frames 3D and 4 – apart from redesigned ducts for spilling boundary-layer air, leading to single rectangular mesh exits on each side of the spine – to be sealed to form a new Tank 1, with its capacity increased (in the MiG-29) from 705 litres (155gal) to 1,710 litres (376gal). Each wing tank is also enlarged from 350 to 400 litres (77 to 88gal)

Thus the internal fuel comprises: Tank 1 1,710 litres (376gal); Tank 2 840 litres (184.8gal); Tank 3 1,800 litres (396gal); Tank 3A 530 litres (116.6gal); new Tank 3B 130 litres (28.6gal); and the wing tanks 800 litres (176gal). Compared with the MiG-29, internal capacity is increased from 4,365 to 5,810 litres (1,278gal). With three external tanks the total is 9,610 litres (2,114gal). The retractable probe, described later, is a customer option.

The engine is the RD-33K, with maximum dry and afterburning ratings of 5,500 and 8,800kg (12,125 and 19,400lb), respectively. This uprated engine has FADEC (full-authority digital electronic control), which of course also controls the nozzles (which are redesigned, somewhat resembling those of the GE F110) and also the variable inlets.

The flight-control system, always of central importance to MiG aircraft, was totally redesigned. The control surfaces have already been described, and their surface power units were little changed mechanically, but in place of the mechanical signalling the pilot input is transmitted electrically via flat multicore cables duplicated along each side of the *centroplan*. After considering digital signals the decision was taken to use analog (infinitely variable voltage or current, rather than discrete bits). Though this may seem retrograde, it has avoided the crashes and prolonged debugging needed by digital fighters in the West. The system is quadruplex (four independent channels) in pitch, and triplex for roll and yaw. In each MiG-29M built so far there is also a mechanical backup. Pilot input is by a central control column, and stick forces are typically halved in comparison with earlier MiG-29s. Unlike the MiG-29 and MiG-29S the limitations on g (design factor remains 9) and angle of attack are 'hard', and cannot be over-ridden merely by exerting greater stick force. On the other hand, the pilot has the option of switching the limits off. With limits on, they prevent AOA from exceeding 35°, compared with 24° for the MiG-29 and 28° for most S versions. General designer Mikhail Waldenburg has expressed the view that a production MiG-29M would probably be cleared to 'a considerably higher value'.

The control column and throttle levers incorporate additional functions to give HOTAS capability. In particular, these two locations for the pilot's hands control the two large (18 × 18cm, 7.1 × 7.1in) monochrome multifunction displays, which also incorporate touchscreen control. The pilot can select the desired radar *regime* from four choices, each with subchoices, slew the antenna manually, change field of view, and perform other control tasks according to the mission and weapons. Both screens are used to provide tactical radar/IR/TV displays, which in the prototypes have been air/ground on the left, with a related mode for navigation, and air/air on the right.

The radar is the Fazotron N010 *Zhuk* (beetle), which like the N019M has a mechanically scanned flat-plate antenna made up of a stack of slotted waveguides, with a diameter of 680mm (26.8in). In the air/air mode it offers the capability of simultaneously engaging four targets out of ten being tracked. It can illuminate targets for semiactive missiles, and also has a gunfire mode. It can provide target designation for surface attack, terrain following or avoidance, real-beam or synthetic ground mapping, doppler speed measurement, and various forms of position fixing. The RLPK computer has a processing speed four times faster than that of the N019M.

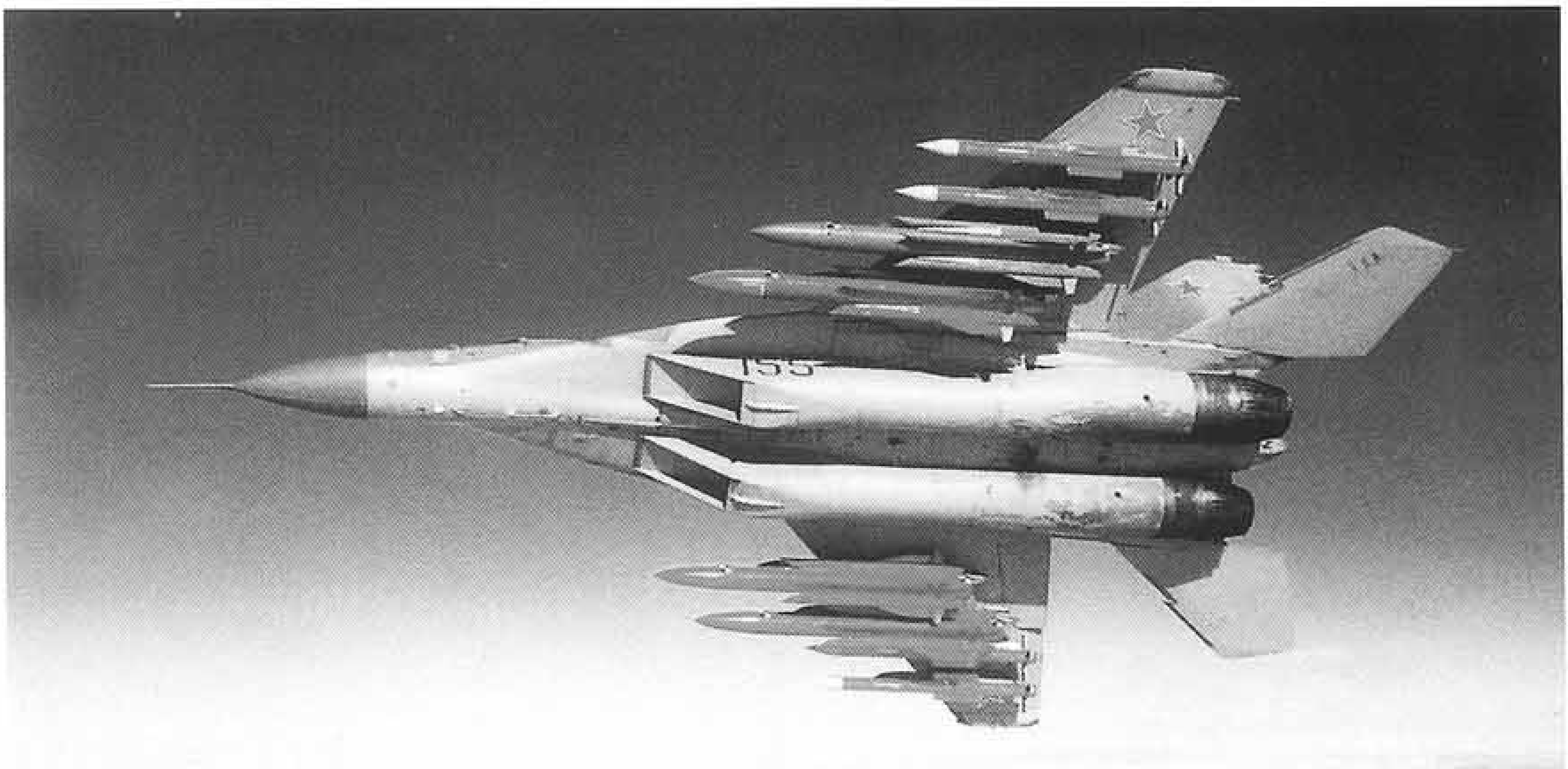
The SUV fire-control system is completed by the HMS (helmet-mounted sight), which has increased angular coverage and whose data-processing speed is also multiplied by four, and the new OLS-M (*optiko-lokatsionnaya sistema*) whose optics are housed in an unchanged glass ball to the right of the windscreen. This system includes a new TV sensor, required for some air-to-ground missiles and for identification of distant targets. The IRST has greater discrimination achieved partly through better cooling, and the laser can illuminate surface targets for other air-to-ground missiles including LGBs. The HUD-sight has a larger field of view, better optics and no opaque bridge across the top.

Each wing is equipped for four pylons, compared with two in the MiG-29 and three in the MiG-29S. Ignoring the centreline tank, the underwing weapon load is increased to 4,500kg (9,921lb), including the full range of Kh-25, Kh-29 and Kh-31 surface-attack missiles. The range of air-to-air missiles has already been described with earlier versions, though with eight pylons new combinations are possible. In autumn 1997 certification with all available weapons had not quite been completed, because of lack of funding.

More than half the items in the complete avionics suite are new or upgraded. The *Tsifra* (number) computers are much more powerful than those of earlier versions, and they link almost every function including maintenance recording. Reliability, maintenance burden, turnaround time and overhaul lives have been particularly addressed in the MiG-29M, the OKB having set itself severe targets not demanded by the government.

The air-data system is upgraded, and has new total-temperature sensors and yaw/AOA vanes on the side and top of the nose. The IFF system is new, with different antennas including two in the fin trailing edges under the rudders. The RWR (radar warning receiver) system is the L-150 *Pastel'* (same word), with greater sensitivity and discrimination over expanded band widths. This system can automatically cue defensive measures. These can include Kh-25MP or Kh-31P anti-radar missiles, and always include the latest internal jammer and new dispensers. The active jammer is *Gardeniya*-1, probably the most capable and well-developed fighter installation in the world and an improved version of the set first fitted to the MiG-29SE. This is installed in the spine, transmitting through modified wingtip antennas. The BVP-60-26 payload dispensers, housing 120 chaff/flare cartridges, are inside the spine, not in front of the fins.

Among other new avionics items is the *Mayak* (lighthouse) radio compass, which uses a new antenna comprising eight parallel strips embedded inside the back of the canopy. The gun, which can be fired with the centreline tank in place, is fed by a magazine reduced in size to 100 rounds. The installation of the APU and aircraft accessory gearbox has been



MiG-29M 'Blue 155' with Kh-31Ps and R-77s. (RART)

improved, and the APU inlet is now in the top of the *centroplan* to the right of the spine. The flat beaver-tail, called a *lopata* (spade), now terminates in a single upwards-hinged tailcone to release two cruciform braking parachutes, each of 13sq m (140sq ft), which stream side by side with excellent stability.

Small changes have been made to the landing gear, the most important being uprating the capacity of the pneumatically operated brakes. As noted earlier, the airframe has been largely redesigned to incorporate new materials and manufacturing processes. The objectives have been to increase strength, reduce structural bulk in order to accommodate more fuel and avionics, increase structural life and facilitate maintenance.

In the MiG-29M prototypes the percentages of materials in the primary structure are: steel 35, aluminium-lithium alloys (almost wholly 1420) 29, aluminium alloys 27, structural composites 6 and titanium alloys 3. At the 1989 Paris airshow one of the more significant exhibits (seen for what it was by a tiny fraction of visitors) was an unlabelled example of Tank 1, forming the front of the *centroplan*, welded as a single unit in 1420 Al-Li alloy. The same material is used for a large part of the structure ahead of the main landing gear and the tapered wing skins above and below the inter-spar box.

The highly stressed structure between Frames 6, 6V and 7 is welded steel, and the engine bays incorporate new alloys of titanium. Because of their very low densities the 6 per cent of composites gives a misleadingly low impression of their importance. Carbon-fibre composites, usually with a honeycomb core, are used for essentially all the movable surfaces on the wings and tail as well as the airbrake and fins. Thanks to their rigidity and lightness, the entire propulsion gondola under each engine is a single very large carbon-fibre structure. This is light enough to be removed in minutes by two men, enabling the entire engine, complete with afterburner, to be lowered on to a trolley, using only a few basic tools.

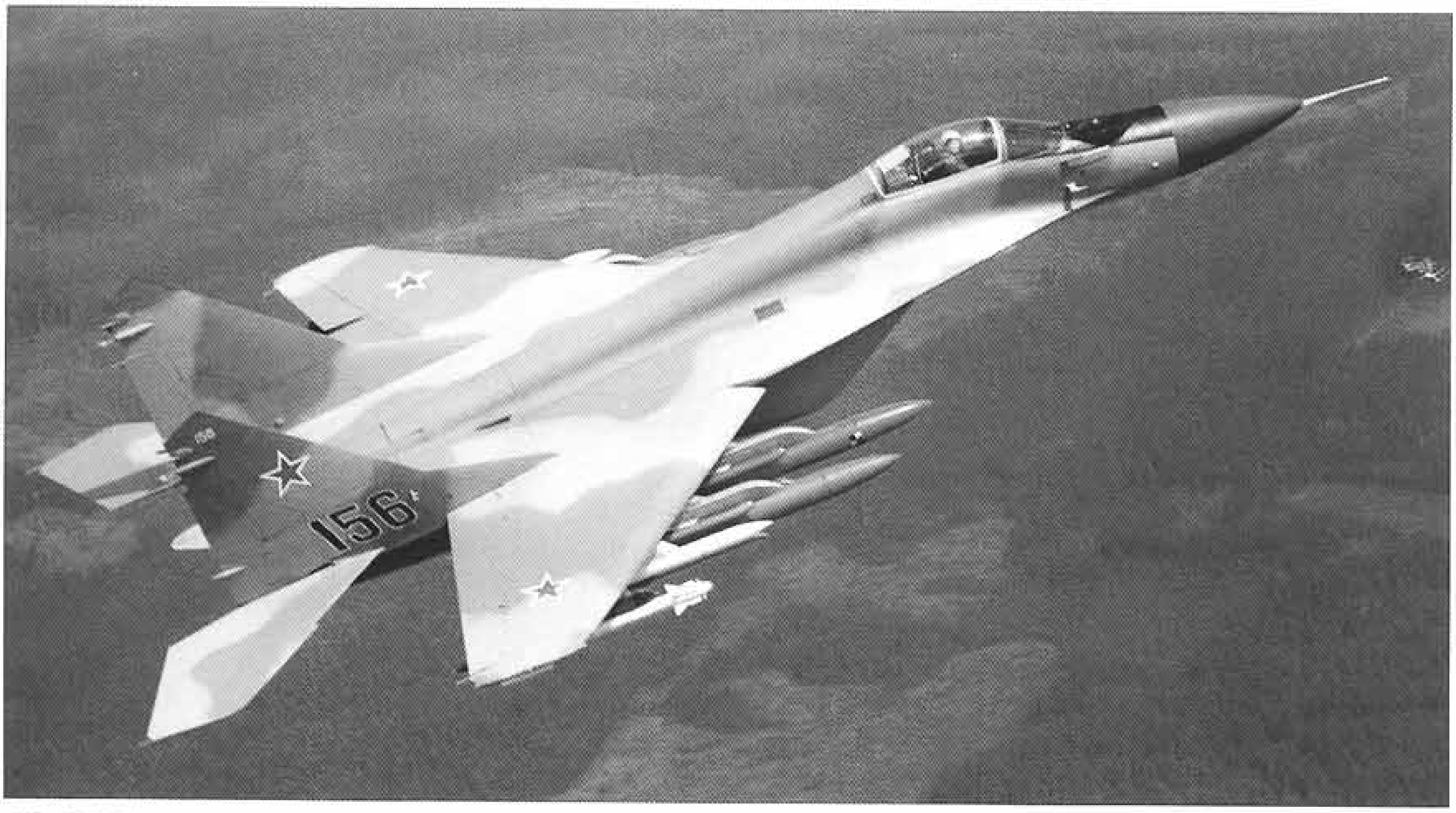
This allows an engine to be changed, even in a harsh environment, in 35 to 40 minutes. The left/right engines are not handed but interchangeable. Airframe design life of a series aircraft would be 4,000 hours or 30 years. Other targets include 11.5 MMH/FH (maintenance man-hours per flight hour), a 1.2hr mean time to rectify any fault, and a front-line mission turnaround time of 15 to 25 minutes.

The OKB constructed six MiG-29M prototypes, F/n 05551–05556, originally callsign 'Blue 151' to '156'. Valeriy Menitskiy flew the first, with RD-33 engines, on 25 April 1986. The first flight with RD-33K engines was on 26 September 1987. Aircraft '151' was used to develop the flight-control system, '152' the aerodynamics and propulsion, '153' the radar, '154' the engines, '155' radar and avionics and '156' avionics/weapon integration. At least the first aircraft had false upper-surface engine inlets painted on.

Until 1994 the OKB expected that MiG-29s of the VVS and A-VMF would be replaced on a one-for-one basis. An initial order for the VVS for thirty was expected – President Yeltsin signed a Memorandum of Understanding to this effect on 28 January 1993 – but despite the outstanding success of this aircraft there has so far been no money available either for a production order or even to complete the last few certification tests with particular weapon combinations.

Inability of the government to fund the production of a successor to the MiG-29 (*see* 1-42 and LMFI entries) has forced the OKB to concentrate on every possible update to the existing worldwide fleet of MiG-29 aircraft. Contrary to what was originally believed, the MAPO-MiG engineers now offer to upgrade any single-seat version to the latest MiG-29M standard. This includes all the airframe modifications, all the avionic improvements, addition of inflight refuelling and a completely new engine nozzle.

The inflight-refuelling installation is particularly neat, and weighs less



MiG-29M 'Blue 156' with Kh-31Ps, R-77 and R-60M. (RART)

than 100kg (220.5lb). The probe is fully retractable, and is compatible with UK/US Flight Refuelling drogues. Flow rate is 600 litres (132gal)/min.

The new engine nozzle is a feature of the RD-133, but retrofittable to the RD-33 and RD-33K. It is a 3-D (circular) nozzle, variable in profile and area, yet capable of being vectored in any direction, not only in the vertical plane. Though the RD-133 nozzle was designed for the MiG-29M with fly-by-wire control, it is capable of being moved by hydraulic actuators controlled by simple additions to the mechanical flight controls of earlier MiG-29 versions. The RD-133 began testing in 1996, and a MiG-29 demonstrator with two of these engines should fly in early 1998 if it is to appear as promised at the 1998 Farnborough airshow. Dr Aleksandr I Ageyev, the former MAPO-MiG director for strategic analysis, called new-build MiG-29M aircraft with RD-133 engines the MiG-35, but this is unconfirmed.

In 1993 the OKB published a drawing of an 'improved MiG-29' with controllable canards and swept-back outer wings. No such aircraft has been flown, and by 1997 the belief was growing that with powerful thrust-vectoring such surfaces should not be necessary (*see* MiG-35).

MiG-33, MiG-29ME

This is the export version of the MiG-29M. The puzzle over the designation arose when, at the first ILA airshow in Berlin, the MiG-29M was placarded as the 'MiG-33'. Belyakov was incensed, but he later relented and the MAPO-MiG management now market the export aircraft as the MiG-33, a designation used previously (*see* later).

Traditionally it has been the practice for export versions of Soviet military aircraft to be downgraded in weapons and avionics, but in today's environment this hardly applies. The OKB and MAPO-MiG have for several years received hardly any income, and as explained in the Introduction desperately need to find customers. It is highly probable that Finland and Switzerland would have selected the MiG-29M in preference to the American F/A-18 had it been offered.

The basic MiG-29M has completed its development and passed all its State tests. In late 1993 chief test pilot Menitskiy said 'I have flown many aircraft during my career, and I can say without reservation that this is the best aeroplane I have ever flown'. He has a reputation for never being satisfied with a fighter's handling qualities. Thus, the product is clearly outstanding. The remaining problems are that the *Sokol* factory still has a number of unsold MiG-29s, and that, unless sufficient profit can be eked out of Indian and Malaysian sales, there is no money to complete qualification of certain weapon fits, including the R-77 and Kh-31P, or to purchase tooling, materials and equipment items necessary to put the MiG-29M or MiG-33 into production. The following data for the MiG-29M would equally apply to any export version.

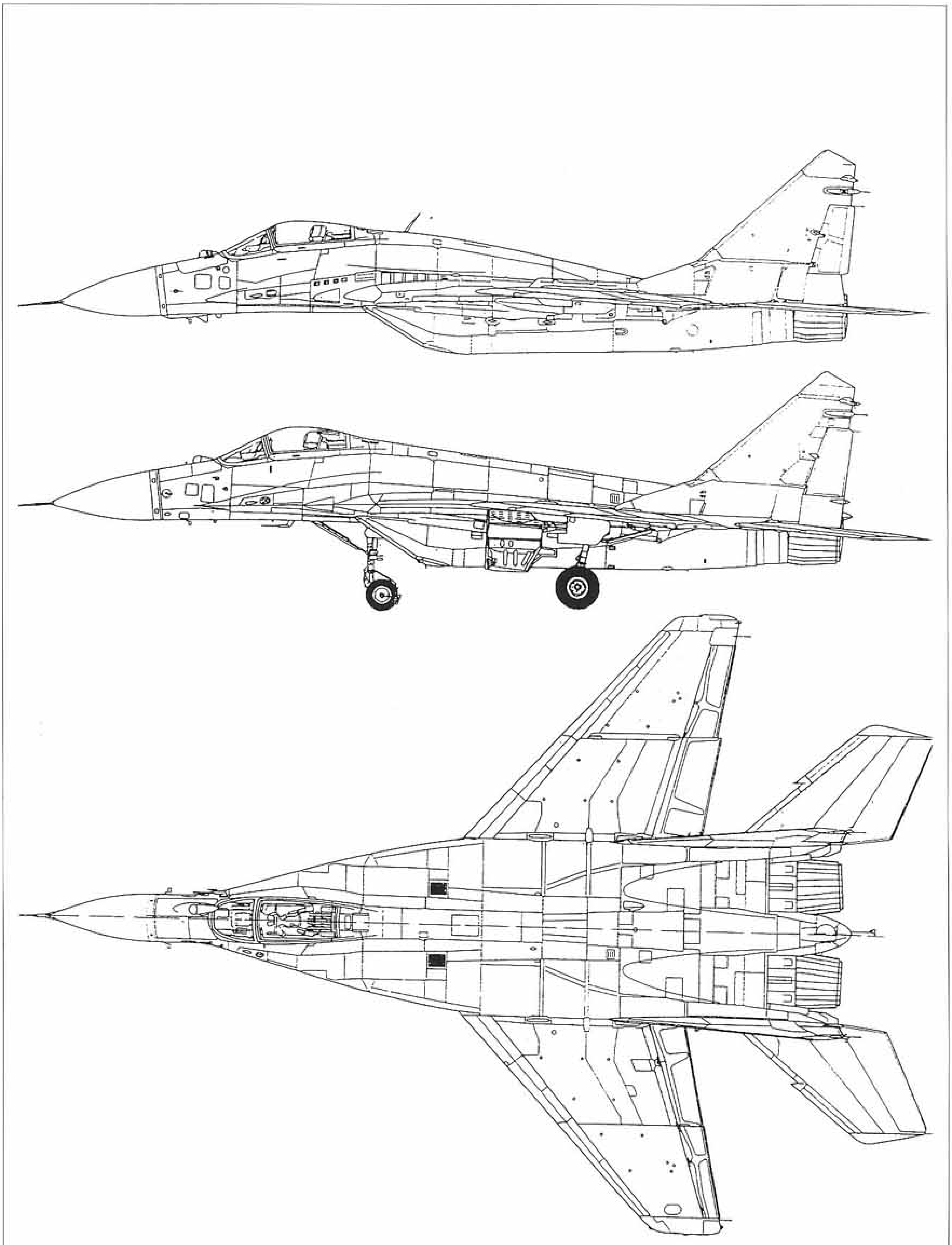
Dimensions as MiG-29 except length 17.37m (56ft 11⅞in).

Weight empty 10,950kg (24,140lb); internal fuel 4,765kg (10,505lb); weight loaded (clean) 15,900kg (35,053lb); normal takeoff weight 16,783kg (37,000lb); maximum takeoff weight 22,000kg (48,500lb).

Maximum speed, climb and ceiling, similar to MiG-29; maximum IAS 1,500km/h (809.5kt, 932mph); steady turn at 3,000m (9,843ft) 23°/s; combat radius (six AAMs and three tanks) 1,400km (870 miles), (3,000kg, 6,614lb, of bombs and three tanks) 1,200km (746 miles); range (internal fuel) 2,000km (1,243 miles), (three tanks) 3,200km (1,988 miles).

MiG-29KVP, 918

In 1980 the VMF, the Soviet Navy, announced a requirement for all-weather interceptors able to operate from the four large 'cruiser-carriers' then being built, to destroy hostile aircraft at the greatest possible radius from the fleet. The term cruiser-carrier was required because plain 'aircraft carriers' would not be allowed to pass



Top: MiG-29SD; middle: MiG-29M; plan view: port, MiG-29M; starboard, MiG-29K.

through the Dardanelles into and out of the Black Sea. The first three of the new ships, in the 67,000-ton class, were to have been the *Admiral of the Fleet Kuznetsov* (ex-*Tbilisi*, ex-*Brezhnev*), the *Varyag* (ex-*Riga*), and the 76,000-ton nuclear-powered *Ulyanovsk*; the fourth, to have been a sister to the third, was never named. The Mikoyan OKB naturally decided to compete for this requirement, and quickly came to the conclusion that they could not do better than develop a navalized MiG-29M.

As a first step, Waldenburg suggested a quick part-conversion of an existing MiG-29 as a proof-of-concept testbed. This could explore the problems of carrier operation and underpin the design of the definitive naval fighter, almost eliminating technical risk (because the non-naval parts would be proven already). It was also expected to be a useful trainer to convert fighter pilots to the art of flying non-V/STOL aircraft from a deck. This aircraft was designated MiG-29KVP, from *korotkii vzlet i posadka*, short takeoff and landing. Its callsign was 'Blue 18.'

The MiG-29KVP was the original 918 prototype, the first MiG-29 fitted with radar. Initially there were only two significant modifications. The tail end of the fuselage was strengthened and equipped with a square-bar arrester hook, hinged to Frame 9 and with the braking-parachute box removed, and all three units of the landing gear were strengthened to accept higher sink-rates on touchdown, with increased oleo travel and main tyres with 14 plies instead of 12. A detail is that the lower part of each fin had a trailing edge inclined back from the trailing edge of the (original narrow-chord) rudder. After these modifications 'Blue 18' was first flown by Aviard Fastovets on 21 August 1982. Several hundred test flights were made from normal runways, from a dummy carrier deck at Saki in the Crimea, from a *tramplin* (ski jump) at Saki and from the *Tbilisi*.

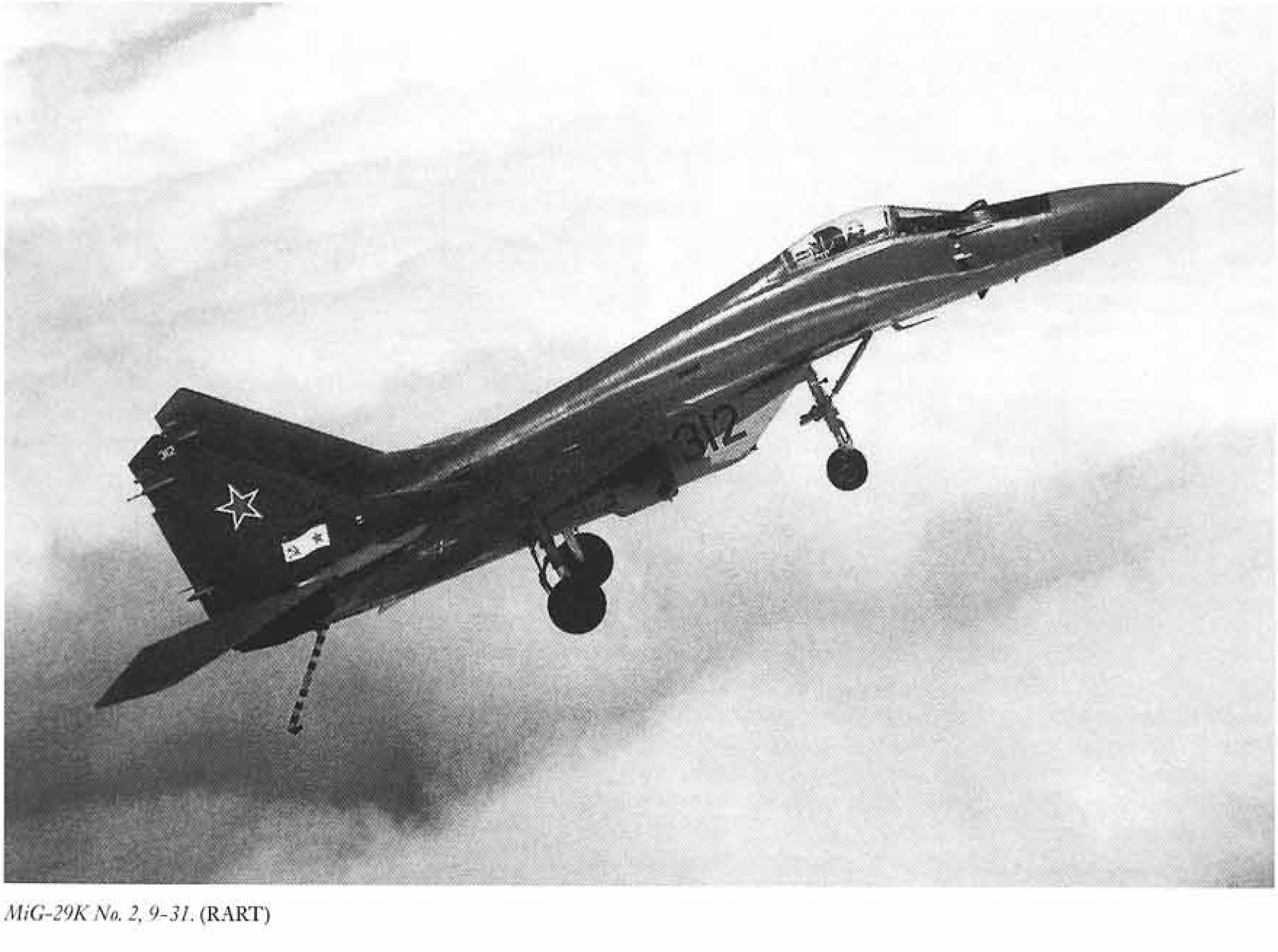
The standard takeoff technique was to run up to maximum thrust against a pop-up deck restraint and then make a free takeoff in less than 100m (328ft) up the ski ramp. The prolonged testing showed that, at maximum weight, the future naval fighter would need increased wing lift and increased engine thrust. The Klimov engine KB qualified the RD-33K to a ChR (*chrezvychainiy rezhim*, exceptional regime) giving 9,400kg (20,725lb) static thrust. This is gained at the cost of reduced overhaul life. Data for this aircraft are similar to those for the MiG-29.

MiG-29K, 9-31

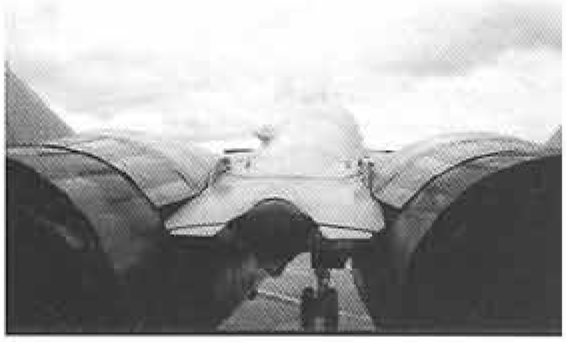
The detail design of the carrier-based naval fighter began in 1985. It was based upon the 9-15, MiG-29M. Fundamental design figures included a flight-control limited angle of attack of 30° and a limiting load factor of 8.5 at subsonic speeds and 6 at supersonic speeds.

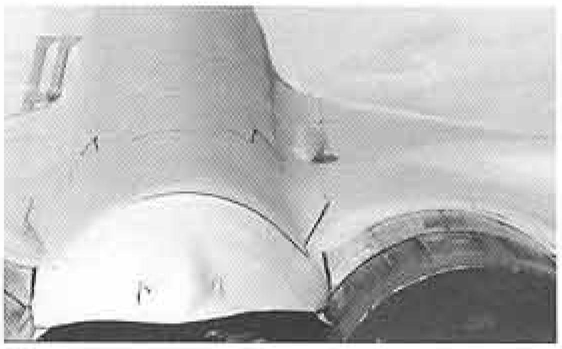
The engines are the RD-33K, with the ChR rating, the installation being identical to that of the MiG-29M. The landing gear and hook are similar to those of the MiG-29KVP, with the addition on the nose leg of a vertical row of red/green/amber 'traffic lights' to indicate to the LSO (landing signals officer) the aircraft's position relative to the carrier glide path. A spotlight illuminates the hook to make its absence obvious to the LSO at night.

The principal modification concerns the wings, outboard of the



MiG-29K No. 2, 9-31. (RART)





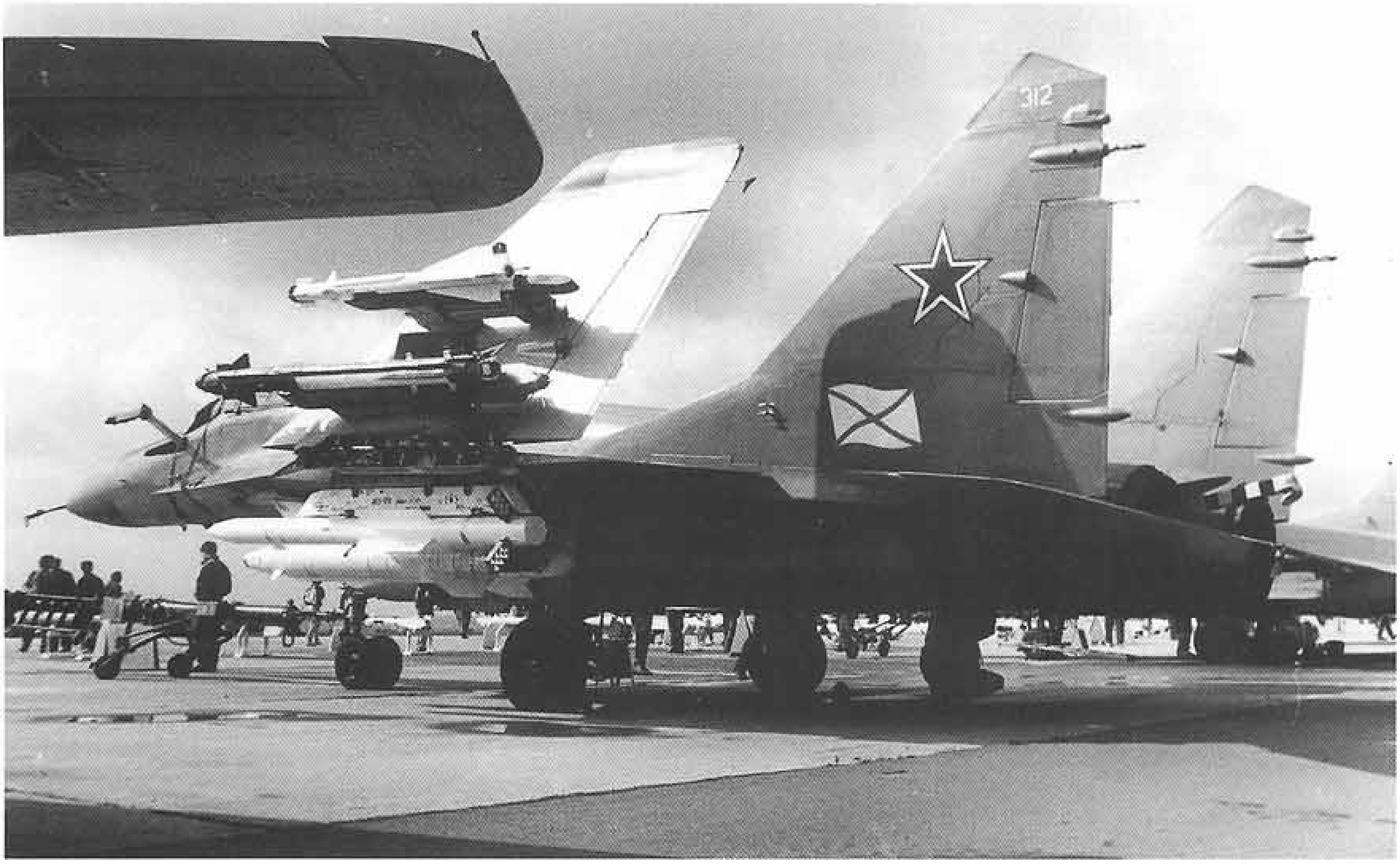
From the left: MiG-29; MiG-29K; MiG-29M. (RART)

unchanged *centroplan*, which have been almost completely redesigned. The only part basically unchanged is the original torque box (integral tank) with three spars attached to Frames 6, 6V and 7. Even this had to incorporate a fold, near the midpoint of each wing. Each wing folds upwards hydraulically at the line of the flap/aileron junction. The row of hinges requires a narrow fairing across the top of the wing box. The fold jacks are powerful enough to raise the wing on a rolling ship in a gale with all pylons at maximum loading.

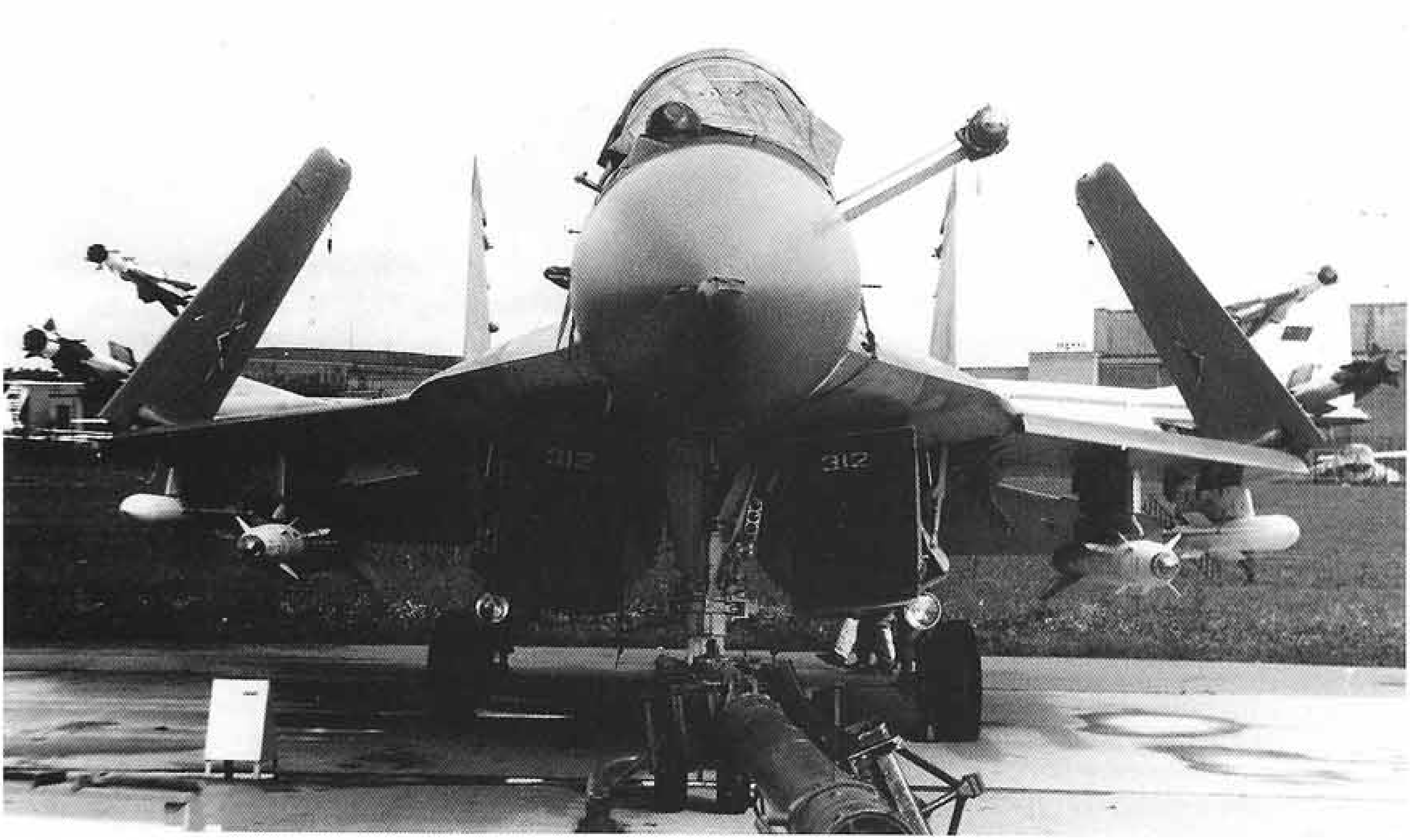
Some sources give a totally wrong account of the MiG-29K wing. Ignoring the new flaps, the trailing edge is moved slightly to the rear, by increasing chord of the structure aft of the main box. The ailerons are the same as those of the MiG-29M (not reduced in span), but to increase lift they droop when the flaps are lowered. Beyond them are attached new composite tips, bulged to accommodate MiG-29M defensive avionics in an improved manner, with slightly repositioned antennas. This tip has greater span and chord than that of the MiG-29M, and a more squared-off shape.

From the front corner of this new tip the leading edge is taken straight to a point on the *centroplan* only slightly ahead of the original junction, slightly reducing sweepback. This substantially increases chord ahead of the wing box, which required the insertion of an additional spar. Ahead of this new spar are more powerful leading-edge flaps. As on the MiG-29M, these are divided into inboard and outboard sections, which always move together. In the MiG-29K they are also divided into front and rear sections (giving four on each wing) which increase camber when depressed. The trailing-edge flaps are completely redesigned, and are of the double-slotted type, with increased chord extending behind the line of the original trailing edge.

Minor changes were made to the secondary-power systems, though the APU and aircraft accessory gearbox are as in the MiG-29M. Avionics are likewise based on those of the MiG-29M, though it was the intention that series aircraft would have not only the *Uzel* (knot) carrier beacon homing of the prototypes but also an inertial navigation system and an ACLS (automatic carrier landing system). The prototypes had an ACLS related to that of the Yak-38, which guided the aircraft to hit the deck within a 6m (20ft) circle with horizontal and vertical speeds controlled within tight lim-



MiG-29K No. 2, 9-31. (photograph by Yefim Gordon)



MiG-29K No. 2, 9-31. (photograph by Yefim Gordon)

its. The airframe was carefully audited to eliminate possible sources of corrosion, and many gaps were sealed.

The OKB factory, now the MAPO Dementyev plant, manufactured two MiG-29K prototypes. The first, callsign 'Blue 311', was first flown by Takhtar Aubakirov at Saki on 23 June 1988. Originally unpainted, it was then camouflaged in VVS grey/green and finally repainted in A-VMF dark sea grey, with Russian Navy flags on the fins. It is fitted with an inflight-refuelling probe, illuminated at night, which is fully faired when retracted. Trials aboard the newly renamed *Kuznetsov* began on 1 November 1989, a major task being the elimination of interference between the carrier's electronics and the ACLS.

The second prototype, 'Blue 312,' was equipped with the full range of weapons, which according to the OKB can reach an overload mass of 9,000kg (19,841lb). Up to six AKU-170 pylons can be fitted. Compatible AAMs are the R-27R1, R-27T1, R-27E(R) and R-27E(T), R-73E and R-77. In the secondary role against surface targets ASMs can include the Kh-25ML, Kh-25P, Kh-29T, Kh-29L, Kh-31P and Kh-31A, plus the KAB-500 LGB and a range of rocket pods. Aircraft '312' has a refuelling probe which when retracted has only the rear part covered by a fairing. This aircraft played a minor role in ship qualification, making six deck landings only.

To the astonishment of observers, the MiG-29K was rejected in favour of more costly Sukhoi aircraft which cannot launch surface-attack missiles. In any case, it is unlikely that any Russian or Ukrainian aircraft carrier will ever go into service. Development of the MiG-29K, for Russian service at least, was terminated in 1993. In 1997, however, negotiations with India for purchase of the carrier *Admiral Gorshkov* had reached an advanced stage, and MAPO-MiG dusted off the entire MiG-29K programme in the obvious expectation that this will become a major type for the Indian Navy.

Span 12m (39ft 4½in); length 17.37m (56ft 11⅞in); wing area 41.6sq m (448sq ft).

Weight empty 11,640kg (25,661lb); internal fuel 4,765kg (10,505lb); weight loaded (clean) 17,700kg (39,021lb), (carrier takeoff) 19,000kg (41,887lb), (maximum after inflight refuelling) 22,300kg (49,162lb).

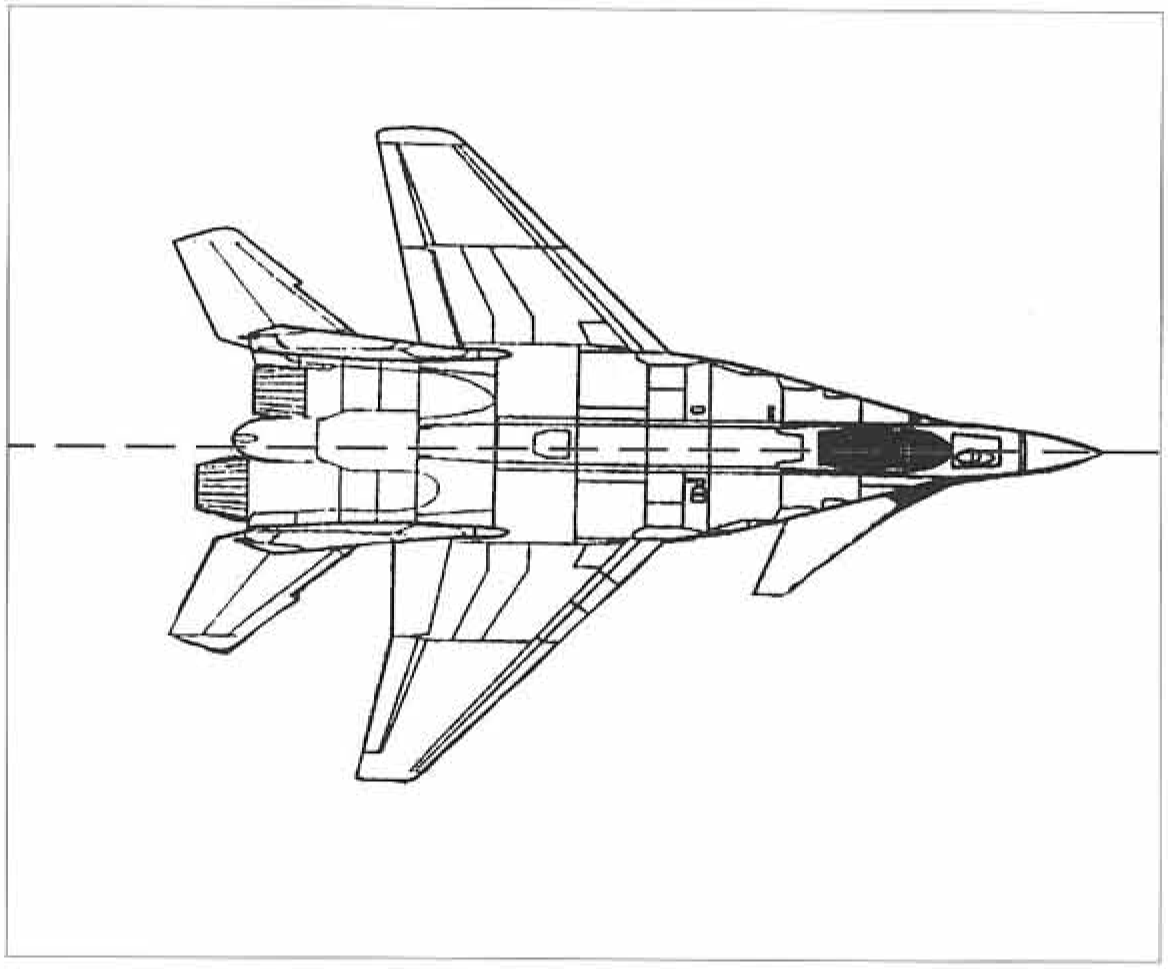
Maximum speed at sea level 1,400km/h (870mph, Mach 1.14), at high altitude 2,300km/h (1,429mph, Mach 2.17); initial climb 260m/s (51,200ft/min); service ceiling 17,400m (57,090ft); range (clean) 1,690km (1,050 miles), (three tanks) 3,000km (1,864 miles); takeoff speed (runway) 260km/h (162mph), (ski jump) 180km/h (112mph); landing speed 240km/h (149mph).

MiG-29KU project

It was agreed that a special aircraft would be needed to teach pilots to operate the MiG-29K from carrier decks. The possibility of adding a stronger landing gear and a hook to the MiG-29UB was examined, but it was concluded that in a high-AOA carrier approach the instructor's view would be inadequate. Accordingly the MiG-29KU (ship trainer) was projected, with the rear cockpit considerably raised. This was similar to the MiG-25RU/Pu and the Tu-128. The aircraft would have had RD-33K engines. It would probably have had a MiG-29K-type wing, but without the bulged tips. This project was abandoned with termination of work on the MiG-29K in 1993.

MiG-35

In 1994 the MiG OKB published a brochure showing a drawing of a 'modernized MiG-29'. In May 1996 this re-emerged as the MiG-35. Features include a new wing with increased sweep to a reduced-chord tip which is moved aft, the rearward shift of centre of pressure balancing that of the centre of gravity. The kinked trailing edge would be occupied by large flaps inboard and sweptback ailerons outboard. The Klimov RD-133 engines, of 8,464kg



Artist's impression of the comparative views of the MiG-29M (port) and MiG-35 (starboard).

(18,660lb) maximum thrust, would be moved 0.92m (36.2in) to the rear to make the aircraft longitudinally unstable and make room for 1,500kg (3,307lb) of additional fuel. Tunnel testing is expected to show whether powered foreplanes will be needed as well as the dogtooth tailplane. MAPO-MiG expect to show a MiG-35 at Farnborough in 1998.

MiG-33 project

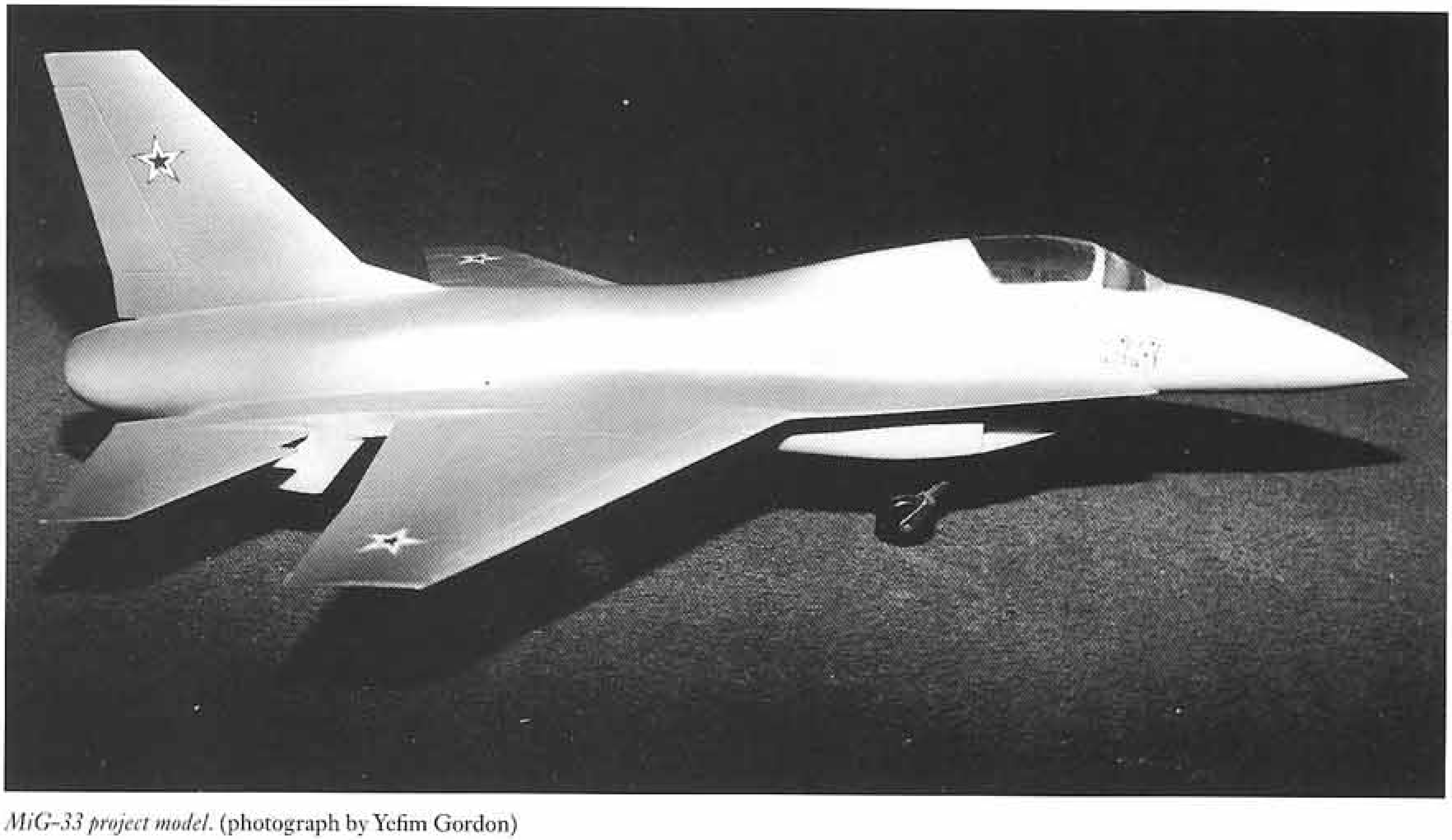
An accompanying photograph shows a project for a small attack aircraft dating from the late 1970s. It resembles a cross between a MiG-29 and General Dynamics F-16, because it has a single fin and a single engine fed by a ventral inlet. Features included a normal fuselage continued to the tail, narrow chines from a vortex-generating claw in line with the windscreen, and an inlet which immediately divided to duct the air past the retracted nose gear.

701

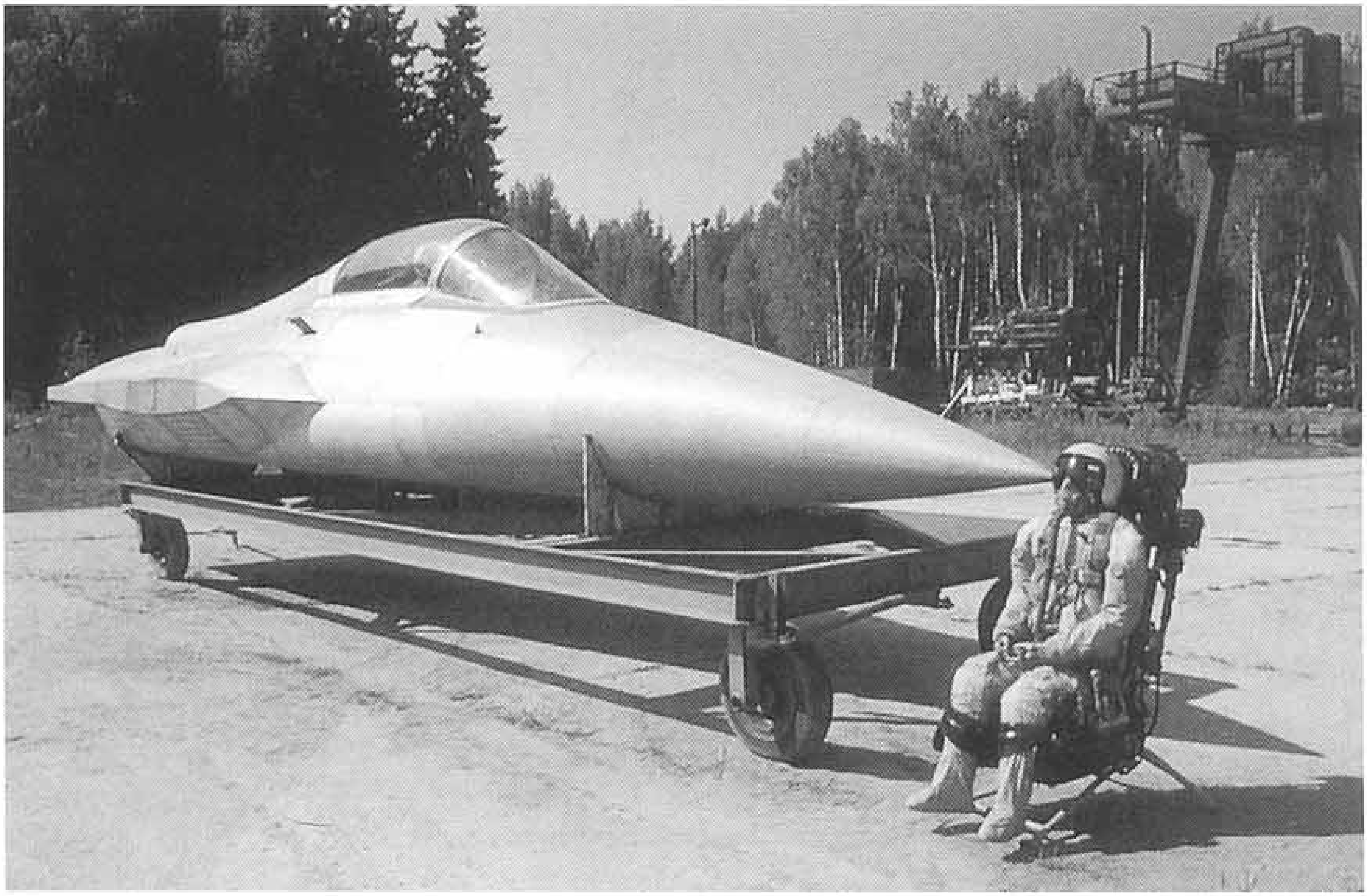
In 1988 Anatoliy A Belosvet, today the MAPO-MiG chief designer and general manager, revealed the existence of *Izdeliye* 701 as an MDP (*mnogofunktsional'nyi dalniy perekhvatchik*, multirole long-range interceptor) to replace the MiG-31. Artist's impressions appeared showing a large tailless delta with twin engines above the rear fuselage, tandem cockpits and internal missile bays. A parallel project was the 701P supersonic business jet. Neither project was proceeded with.

1-42, MFI

In 1983 planning began for the next-generation MFI (*mnogofunktsional'nyi frontovoy istrebitel'*, multirole frontal [tactical] fighter). This was to



MiG-33 project model. (photograph by Yefim Gordon)



1-42 forward fuselage on ejection-seat test. (RART)

be the successor to the MiG-29, for both Soviet and export customers. It was to be the most agile aircraft possible, large enough to have long range with powerful radar and other sensors and a heavy load of air-to-air and air-to-ground weapons, and to incorporate as much as possible of what is popularly called stealth technology. In all essentials the MFI was to be a Soviet counter to the USAF's Advanced Tactical Fighter, which today is proceeding to production as the Lockheed Martin F-22. Aerodynamic and engineering design began in 1984, in which year the AL-41 was selected as the engine (*see* Appendix 1). Each is rated at nearly 20,000kg (44,000lb) in maximum afterburner, and is fitted with a two-dimensional (rectangular) vertically vectoring nozzle. The 1-42 was designed to supercruise in dry thrust. Two teams competed to provide the radar, Fazotron with the N014 *Zhuk*-RN and NIIP with the N011M. Both are high-power sets with a phased-array antenna in the nose of the aircraft similar in size to the MiG-31M's SBI-16. A second antenna faces aft from the tail of the aircraft.

Though various drawings of the 1-42 have been published, none is accurate in detail. The configuration is that of a twin-tailed delta, with or without powered foreplanes used for control in pitch only, supplementing trailing-edge flaps and ailerons and the vectoring nozzles which augment control about all three axes. The engines are fed from a variable-geometry ventral inlet which, like that of the 'MiG-33' model, is only just ahead of the compartment for the nose landing gear.

Other features include a high cockpit giving excellent all-round view (*see* the photograph of the ejection-seat test fuselage), the main landing gear resembling that of the MiG-29 but stronger, and a large dorsal airbrake. It would be reasonable to suppose that a gun is fitted in a wing root, missiles or surface-attack weapons in an internal bay, and an electro-optical (IR and laser) sensor and retractable probe near the windscreen. The 1-42 has been described as broadly similar in size to the Sukhoi Su-27 family. Clean gross weight (and external loads would probably be confined to long-range tanks) is said to be 'about 30 tonnes, 66,140lb'. No 1-42 was ever built.

1-44

This is reported to be the designation of two proof-of-concept aircraft, which the OKB, now part of MAPO-MiG, has actually built. These combine the airframe, flight-control system and engines of the 1-42, but not the mission avionics and weapon systems. The first was reported to be almost complete in 1994, but the start of flight testing at Zhukovskiy was delayed, first by a brief wait for engines, and then by a prolonged wait debugging the flight-control software. This is exceedingly complex, as it controls not only the aerodynamic surfaces but also the engines and their nozzles. Delays have also been caused by the *agregat*, the complex engine-driven accessory gearbox. Far more serious is the underlying lack of money.

Taxi testing is said to have begun in 1994, and with adequate funding flight testing could probably have begun (four years behind the original schedule) in 1995. In June of that year the first 1-44 was shown to the Russian Minister of Defence. Unfortunately, a crippling shortage of money has not merely delayed the programme but, according to a Tass report of 18 March

1997, brought about its cancellation. According to Mikhail Waldenburg, a major factor in the decision to transfer engineers to other projects is the fact that few export customers could afford aircraft in this class, and MAPO-MiG cannot survive without exportable products. The company is now concentrating on improving the MiG-29 and in planning for the LMFI.

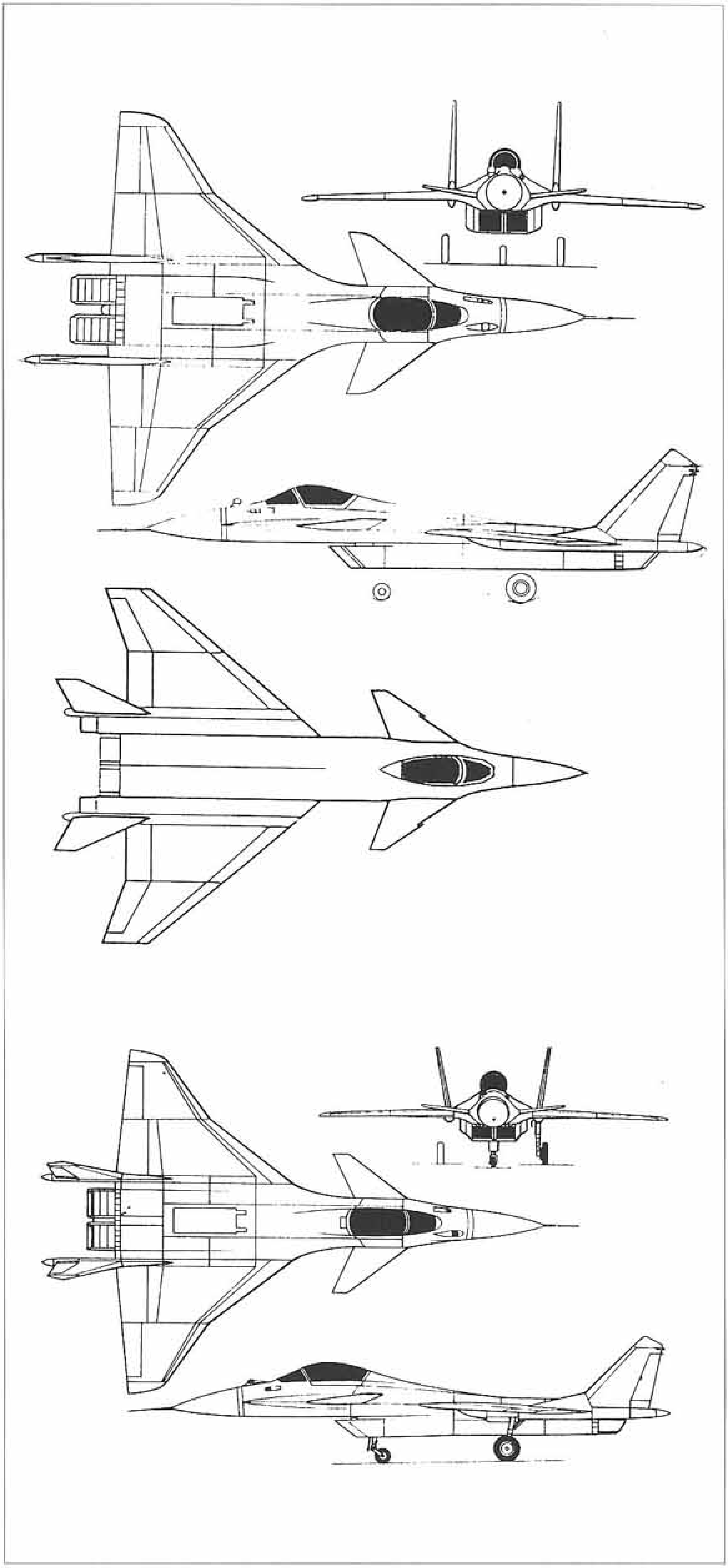
LMFI

Following the collapse of the MFI as being unaffordable, the MiG (occasionally now written MIG) design bureau has started afresh. It accepts that there is no chance of its being able to provide a direct counter to the F-22 (this might be achieved by Sukhoi) and instead planning is proceeding on a Russian equivalent of the JSF (Joint Strike Fighter). Designated LMFI (*lyogkiy mnogofunktsional'nyi istrebitel'*, light multirole fighter), this is envisaged as a smaller aircraft than the MFI.

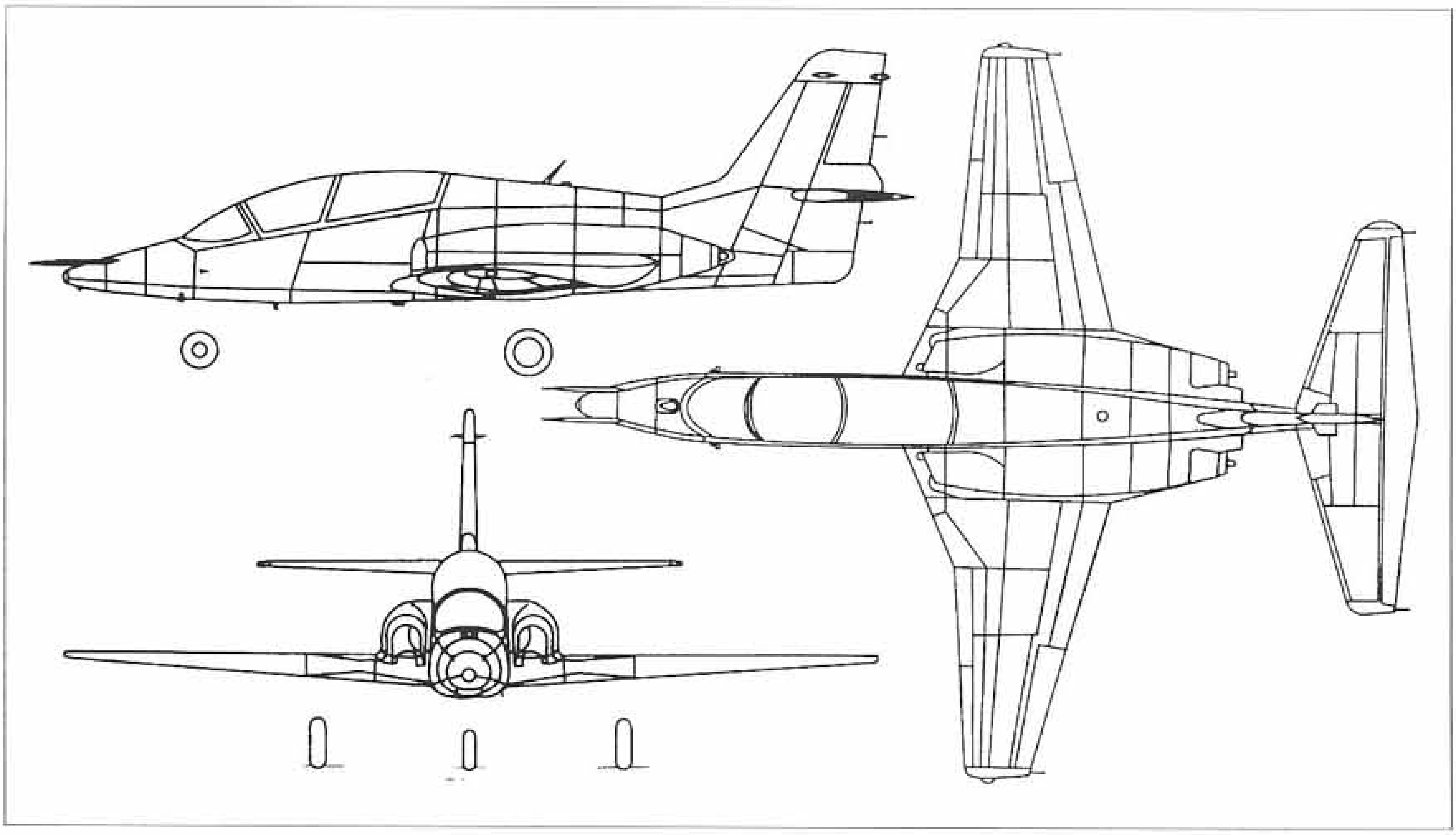
Instead of Dr Viktor Chepkin's AL-41 the engine will be the RD-333 from Klimov Corporation in Leningrad. Despite its designation it is not derived from the RD-33/RD-133 but is a new design (*see* Appendix 1). The LMFI will be twin-engined, with three-dimensional vectored nozzles and STOL (possibly STOVL) performance. General Designer Waldenburg believes it should be possible to dispense with foreplanes. In his view 'The LMFI must be the best light fighter of the 2020s, otherwise the effort will not be worthwhile'. Should this project succeed in proceeding to series production it might become the MiG-37.

MiG-AT, MiG-ATS, MiG-AS

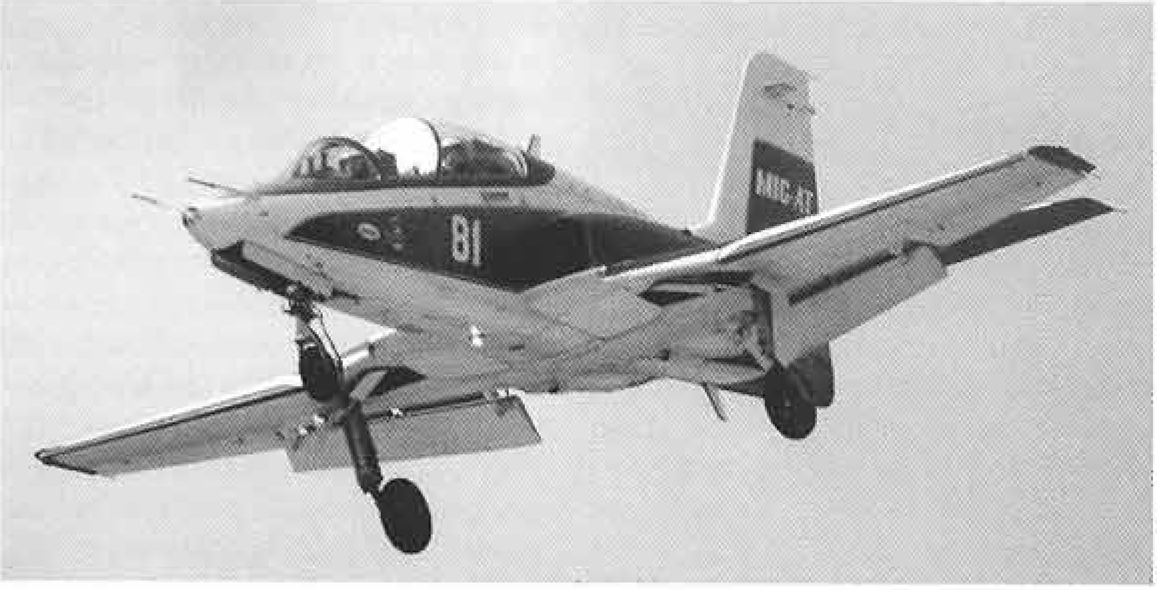
In the late 1980s the VVS (Soviet Air Force) issued a requirement for an initial 200 examples of a new pilot trainer to replace the Czechoslovak L-29 and L-39. Mikoyan was one of five OKBs which competed, and was one of two finalists selected in May 1992. The



A selection of 1-44 drawings published in the West, all largely invention.



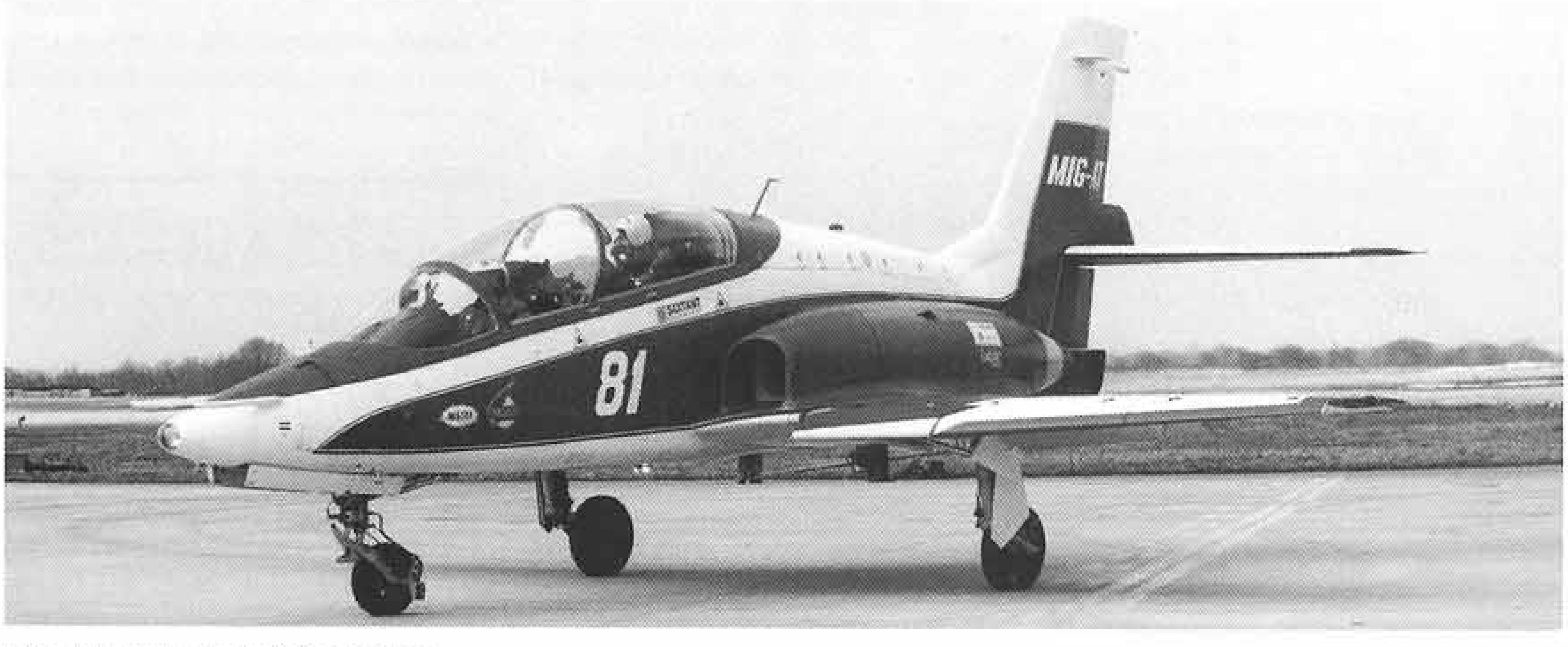
MiG-AT.



MiG-AT. (photograph by Yefim Gordon)

design was wholly conventional, with an unswept wing and T-tail, stepped tandem cockpits and two Klimov R-35 (DV-2) turbofans mounted above the wing roots.

By this time the collapse of the Soviet Union had resulted in existing defence contracts becoming invalid, and with the future increasingly uncertain MiG made approaches to foreign partners. In October 1992 an agreement was concluded with a group of French companies for the joint development of a complete training complex. This comprises the aircraft (Mikoyan Aviation Scientific-Industrial Complex, with the wing subcon-



MiG-AT. (photograph by Yefim Gordon)

MiG-AT. (OKB)

tracted to Daewoo of South Korea), engines (Turbomeca-SNECMA), avionics (Sextant Avionique, assisted by Thomson-CSF and SFENA), hydraulics and landing gear (Messier-Bugatti), electrical system (Auxilec) and computer training simulations and software (GosNIIAS, State Research Institute for Automated Systems).

The prototype, code 'White 81' and later '821', was rolled out from the *Zenit* Machine-Building factory (former OKB prototype works) on 18 May 1995. By this time the design had been significantly altered, notably in moving the horizontal tail down from the top of the fin and in switching to French engines. The latter are the Larzac 04-R20, each rated at 1,440kg (3,175lb) thrust, mounted in a titanium bay above the trailing edge of the wing and fed by a duct from a simple inlet set a short way back above the leading edge to minimize foreign-object ingestion. For the Russian market – assuming a substantial order – these engines would be made under licence by the Chernyshov Production Enterprise (a producer of MiG-29 engines).

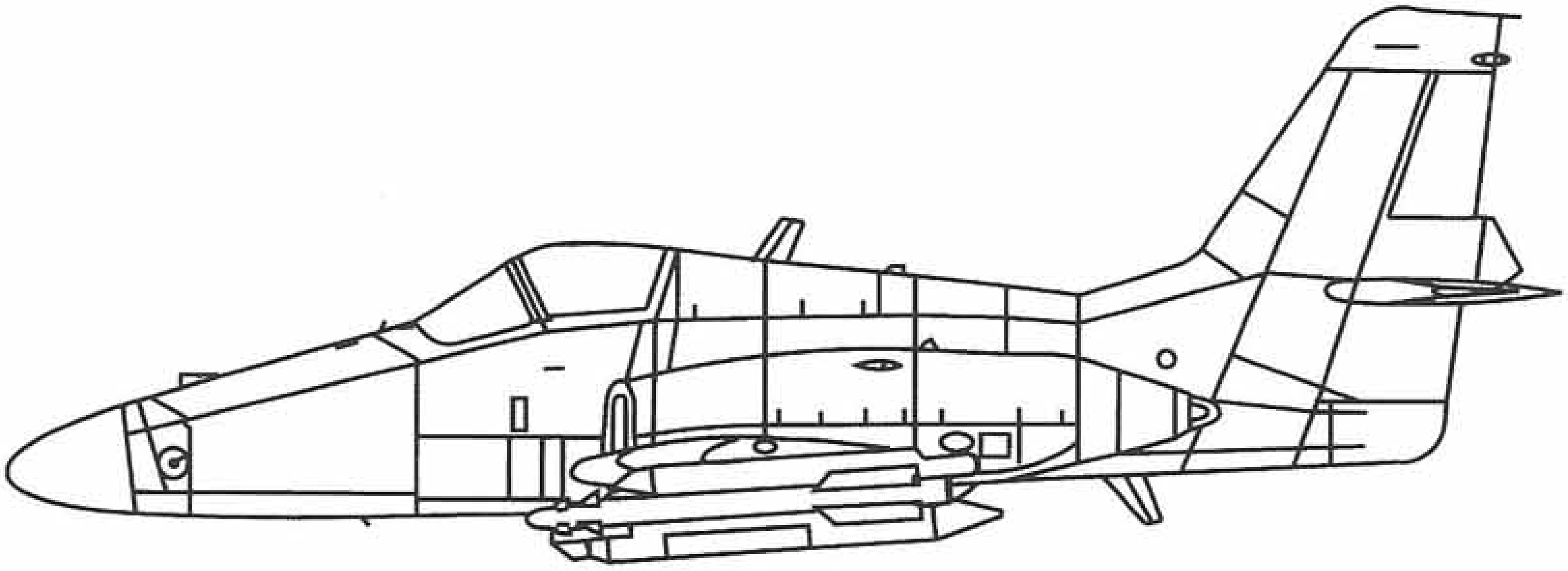
The flight-control system is fly-by-wire, originally developed by Mikoyan with the GosNIIAS institute. Dangerously extreme angles of attack are avoided by a stick pusher. Control surfaces, which are all carbon-fibre honeycomb, comprise conventional ailerons, elevator and a small rudder above the elevator. On each wing are three sections of leading-edge slat and a single slotted flap. The tail end of the fuselage splits to form twin airbrakes, and as these open into the jets they are made of titanium alloy.

The pupil and instructor board via fold-out steps and sit in Zvezda K-93 zero/zero seats mounted on backwards-leaning bulkheads. The windscreen is a frameless wraparound birdproof moulding, and the large canopy over both cockpits hinges to the right. So do the two large composite doors which cover the equipment and avionics housed in the spine. A total of 2,390 litres (526gal) of fuel is housed in a large cell between the engines and an integral tank in each wing.

The steerable nosewheel has a 500 × 150mm tyre and retracts forwards. Each main wheel has a 660 × 200mm tyre and is carried on a long-stroke trailing levered-suspension link and retracts inwards. Track is 3.8m (12ft 5⅝in) and wheelbase 4.43m (14ft 6½in). The right engine drives a pump in the General hydraulic system, and the left drives a pump energizing the Booster system which, as in MiG fighters, drives one chamber in each tandem-duplex surface power unit.

All avionics are integrated by a digital data bus meeting MIL-1553B standards. The flight-control avionics comprise a UMT33 air-data unit served by two probes above the nose, with navigation provided by NSS-100S-1 GPS, a *Totem*-200 laser-gyro inertial platform and NC-12B Tacan. A *Tester*-U3A

MiG-ATS at the MAKS-97 airshow. (photograph by Yefim Gordon)



Projected MiG-AS tactical fighter. (OKB)

flight-data recorder, EVS-915 video recorder and *Almaz*-UBS voice recorder are fitted, together with ERA-2000 vhf/uhf radio, NR-510A-101 VOR/ILS, SG-100 IFF and SPU-821 intercom. Each cockpit has two MFD-55 colour multifunction displays, and the pupil's cockpit is fitted with blinds for IFR training. The instructor can simulate various emergencies.

The first prototype was exhibited at the Paris airshow in June 1995. It began taxi testing in August 1995, but did not make a (brief) first flight until 16 March 1996, the first proper flight following five days later. Thanks to income from the export of MiG-29s to India and Malaysia MAPO has been able to construct ten MiGATs. Two are to be used for ground testing, and two for flight testing (the No. 2 prototype first flew on 22 September 1997). The remaining aircraft are expected to fly in 1998, and to take part in a fly-off competition against the Yak-130 for the series contract for the Russian Air Force. According to MiG-AT chief designer, Anatoliy Popov, all ten existed in late 1997.

In September 1997 MAPO-MiG signed contracts worth about 230 million French francs (US$39 million) for a further twenty engines from SNECMA and twenty-five complete avionics installations from Sextant.

The standard trainer is equipped with a centreline attachment on which can be hung various stores including gun pods, such as the UPK-23-250, and one pylon under each wing. For combat training it is possible to attach seven pylons, two being under the wingtips for air-to-air missiles such as the R-73E or Magic. MAPO-MiG are also marketing two derived versions. The MiG-ATS combat trainer is a dual-control aircraft with a guidance pod for air-to-surface weapons. At the MAKS-97 airshow the ATS prototype (the third aircraft, code 83, 823 being a static-test airframe) was exhibited statically, painted grey. The first flight was in November 1997. It carried a gun pod, rocket launcher and LGB, and the cockpit showed Russian avionics. The single-seat MiG-AS (MiG-AC in Russian) light tactical fighter/attack version would have a radar and inbuilt gun 'for all-weather use of air-to-air and air-to-surface missiles'.

MAPO-MiG expect by 2002 to switch from the Larzac engine to the more modern Aviadvigatel D-1700. They add that all versions can be modified for operation from an aircraft carrier. Brochure price is US$12 million (spring 1996).

Span 10.16m (33ft 4in); length 12.01m (39ft 4⅞in); wing area 17.67sq m (190.2sq ft).

Weight empty, about 3,280kg (7,230lb); weight loaded, varies from 4,610 to 7,000kg (10,163–15,342lb).

Maximum speed at sea level 850km/h (528mph), at 2,500m (8,200ft) 1,000km/h (621mph); rate of climb at sea level 67m/s (13,189ft/min); service ceiling 15,500m (50,853ft); range (internal fuel) 1,200km (746 miles), (ferry, with tanks) 2,600km (1,616 miles); takeoff speed 180km/h (112mph); takeoff run 310m (1,017ft); landing speed 175km/h (109mph); landing run 540m (1,772ft). These are brochure, not measured, figures.

Konversiya projects

With the near-collapse of its enormous home market for combat aircraft the OKB, now within MAPO, has striven to launch programmes for civil aircraft, if possible with foreign partners. So far the only aircraft actually being built are two light aircraft not of MiG design, the Interavia I-1L two-seater and the derived SL-39. Accordingly, with one exception, the projects originated at the OKB are covered only briefly.

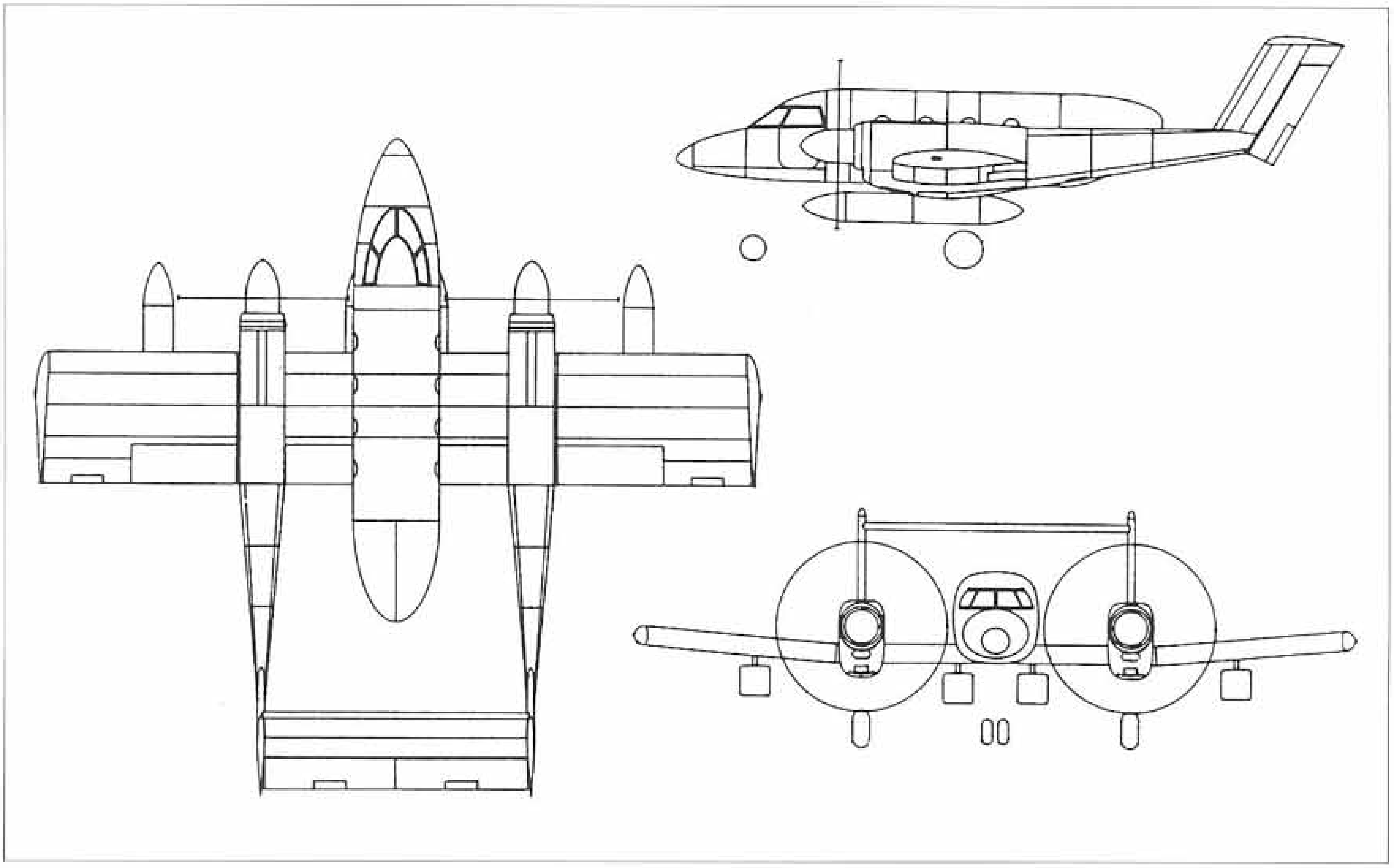
Gliders

Prototypes have been produced of two simple training gliders. The PPO-1 *Chibis* (lapwing) has a wing area of 12sq m (129sq ft) and has empty and gross weights of 90 and 200kg (198 and 441lb), respectively. The two-seat PPO-2 *Kuznechik* (grasshopper) has a wing area of 15sq m (161.5sq ft) and has empty and gross weights of 115 and 276kg (253.5 and 608.5lb), respectively.

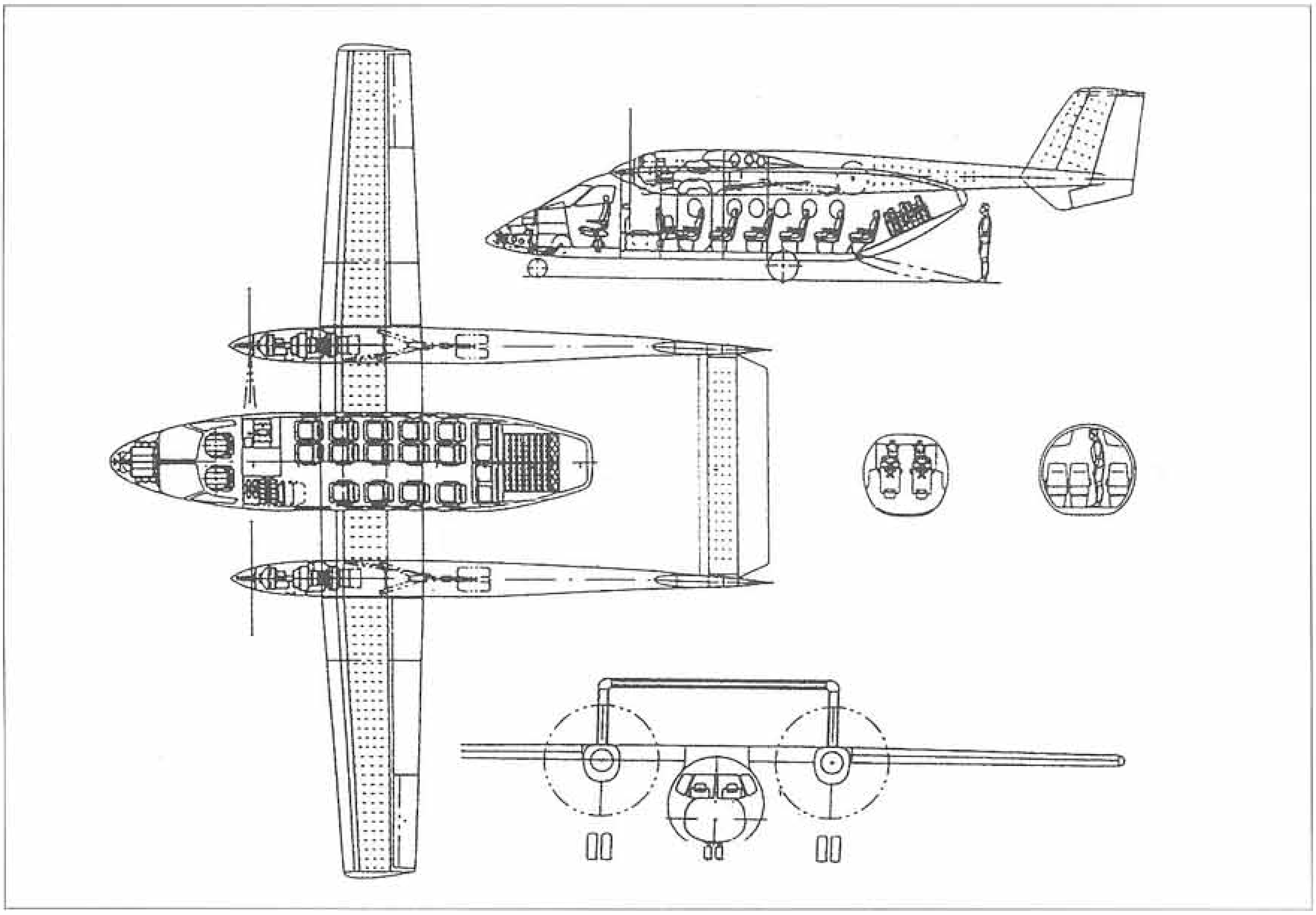
MiG-101M

Multirole STOL twin-turboprop utility transport. Light-alloy and composite structure, untapered low wing with plain leading edge, high-lift flaps and outboard ailerons, central nacelle with two-seat cockpit and unobstructed cabin 4m (13ft) long, 1.48m (58in) wide and 1.6m (63in) high accessed by full-section clam-shell doors at the rear, two 2,500hp TV7-117 turboprops burning a range of fuels including diesel, twin fins carried on tail booms behind the engines joined by high tailplane with split

PPO-1 Chibis. (RART)



MiG-101M.



MiG-101N

left/right elevators, retractable landing gear with twin nosewheels. Intended to carry up to 4,000kg (8,818lb) payload in remote regions.

MiG-101N

High-wing commuter transport for nineteen passengers, in 9,000kg (19,840lb) class with twin tail booms but longer-span wing, 1,300hp TVD-1500 turboprops, level floor near ground with rear ramp door, payload 1,700kg (3,748lb).

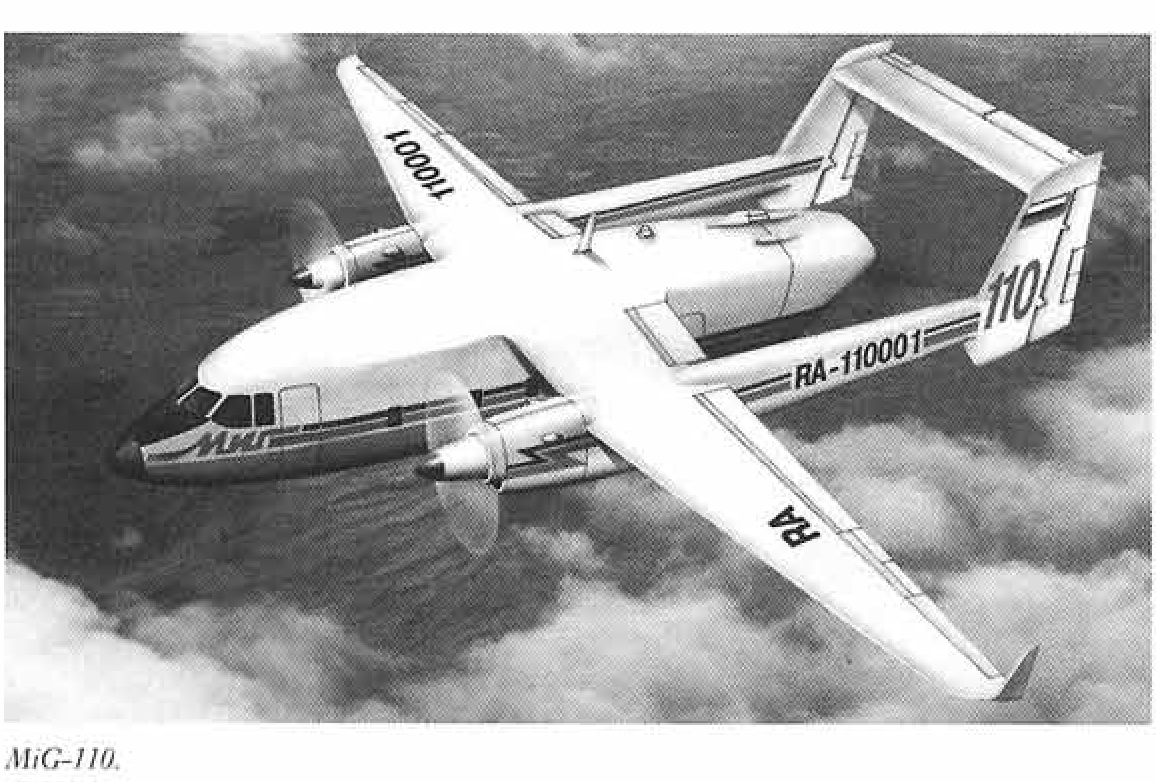
SVB

Larger high-wing twin-turboprop (2,500hp TV7–117 engines) with single-fin tail carried on fuselage, with cabin 2.96m (116.5in) wide seating 50 (3 + 2) or 5,000kg (11,020lb) cargo.

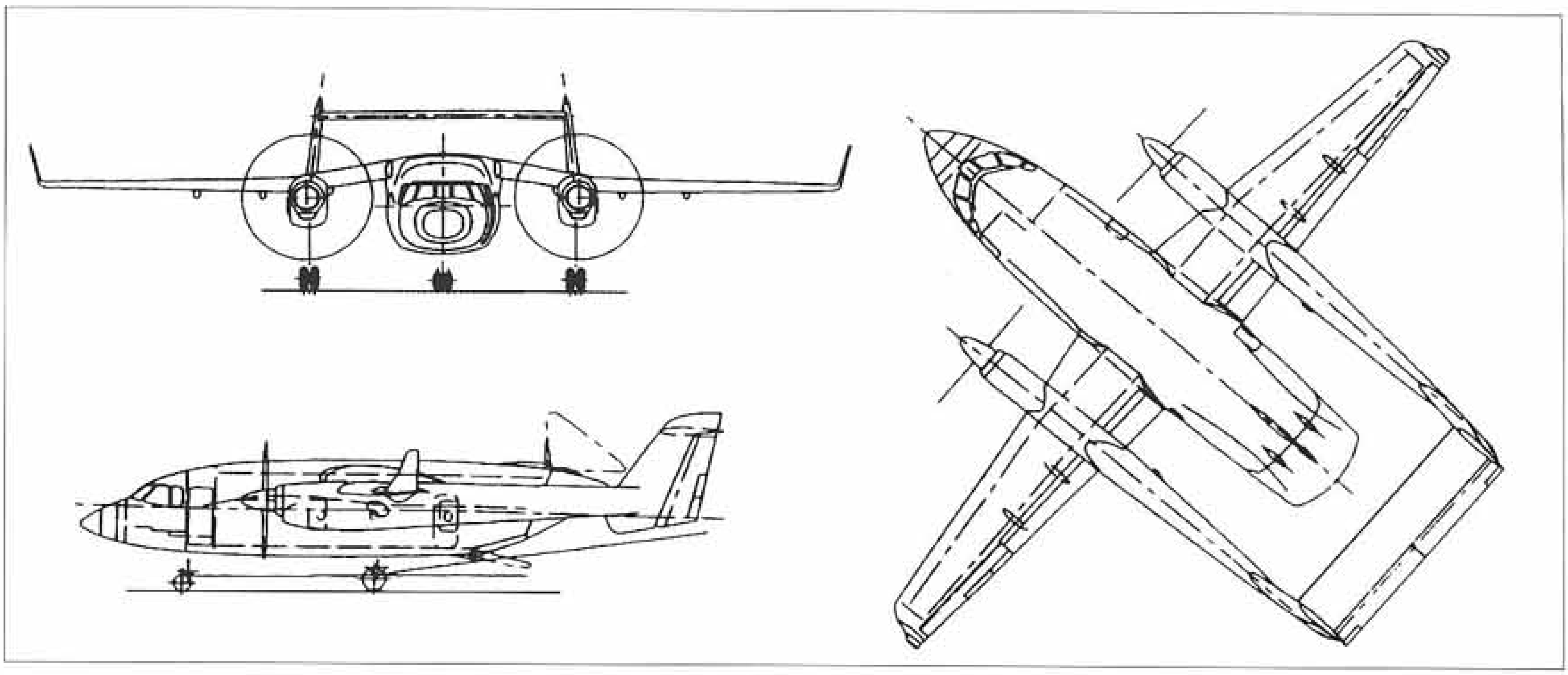
MiG-110

This twin-turboprop was what finally emerged from the -101M, -101N and SVB, and has some features of each. The wing is mounted at the top of a central nacelle with a pressurized cabin 7.4m (24ft 3in) long and with a cross-section 2.2m (86.6in) square. This wing has slats and double-slotted flaps, and the inboard portion has anhedral to the engines to reduce the height of the backwards-retracting main undercarriage, the outer panels being almost horizontal. The twin-fin tail is carried on booms behind the 2,465shp TV7-117SV engines, which drive Stupino six-blade reversing propellers.

Payloads can include up to 48 passengers or 5,500kg (12,125lb) of cargo including vehicles loaded up the rear ramp door. In January 1994 MAPO received government approval for prototype construction, but so far funds have not proved sufficient. This nevertheless appears to be the most likely *konversiya* project to go



MiG-110.



MiG-110.

ahead. A full-scale mock-up was completed in 1997.

Span 24.96m (81ft 10⅝in); length 18.6m (61ft ¼in); wing area about 50sq m (538sq ft).

Weight loaded 18,000kg (39,683lb).

Cruising speed 500km/h (311mph); range with 30 minutes reserve (maximum fuel and 2,660kg payload) 3,775km (2,346 miles), (4,500kg payload) 1,680km (1,044 miles); takeoff run 600m (1,969ft).

MiG-115

In mid-1997 the latest project by MAPO-MiG was this multirole utility aircraft, the newest of many attempts to replace the An-2. Though a totally new design, made of modern stressed-skin and composites, the MiG-115 is again a biplane. Where it is unusual is that the tapered and unbraced wings are widely displaced longitudinally. The separation is too far to be called negative stagger, and in fact MiG call the -115 a tandem-wing design.

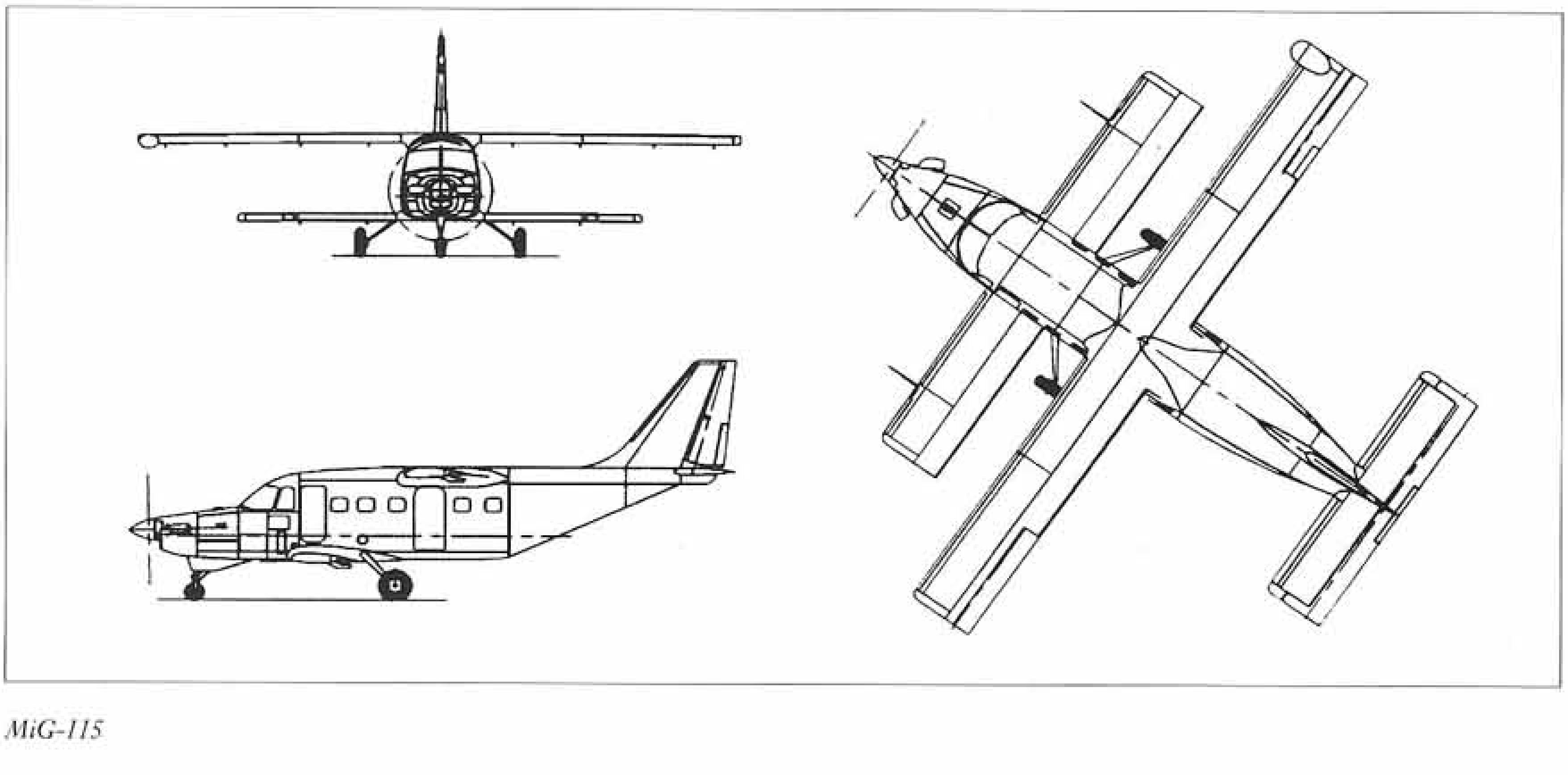
All four wings have slotted flaps hinged to brackets below the wing, and the upper wing also has ailerons. There is also a tailplane and elevators. The engine would be either a 1,400shp TVD-20M or a 1,341shp Klimov (Pratt & Whitney Canada licence) PT6K-67, in each case driving a Stupino six-blade propeller. The cabin would measure 5.1m (200in) long and 1.80m (70.9in) high, with a floor width of 1.82m (71.7in). There could be one or two pilots, with comprehensive avionics, and typical loads could include sixteen passengers, or nine passengers plus 500kg of cargo, or 1,500kg (3,307lb) of cargo.

The basic design was roughed out in 1994. General Designer A A Belosvet says that 'given sufficient financial aid', the MiG-115 could be built, flown and certificated within three years.

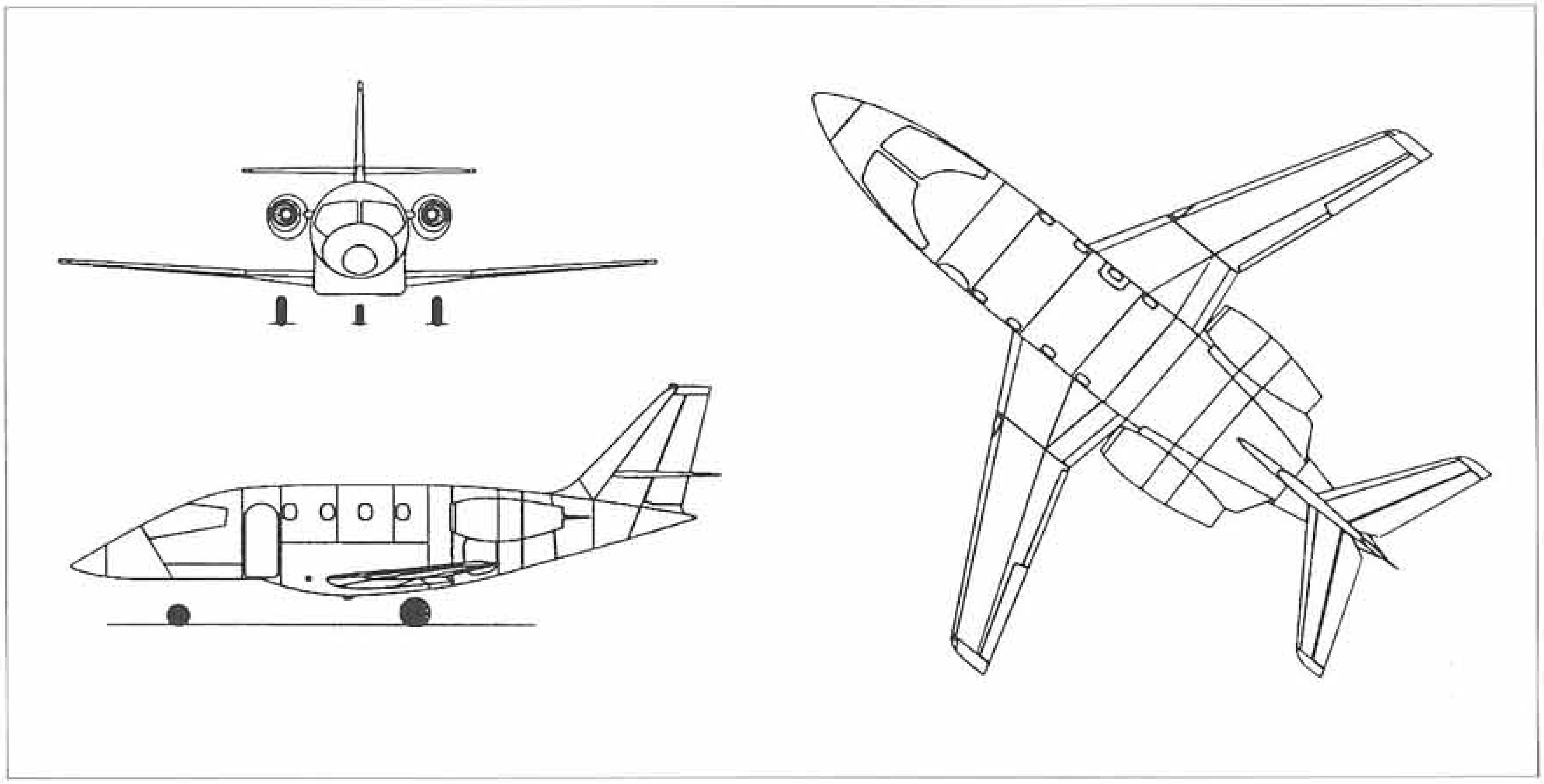
Span (front) 12.2m (40ft), (rear) 15.94m (52ft 3½in); length 14.66m (48ft 1⅛in).

Weight empty 3,332kg (7,346lb); internal fuel, normal 870kg (1,918lb), maximum 1,700kg (3,748lb); weight loaded 5,700kg (12,566lb).

Maximum speed 410km/h (255mph); cruising speed 340km/h (211mph); range with 1,316kg (2,901lb) cargo 1,500km (932 miles); range with 9 passengers 2,200 km (1,367 miles); takeoff run 370m (1,214ft); landing speed 114km/h (70.8mph); landing run 245m (804ft).



MiG-115



Proposed MiG-125. (OKB)

MiG-125

This project by MAPO-MiG is aimed at providing a relatively affordable light business jet tailored for the Russian market, but able to compete internationally. Powered by two Williams Rolls FJ44-2 turbofans each rated at 1,043kg (2,300lb), it would have a slightly swept wing with good high-lift devices, and a circular-section fuselage accommodating a cabin 3.45m (136in) long, 1.65m (65in) high and 1.67m (65¾in) wide. Normal seating would be for one pilot and up to seven passengers. It is proposed to use Western FAA/JAA-certificated avionics and systems.

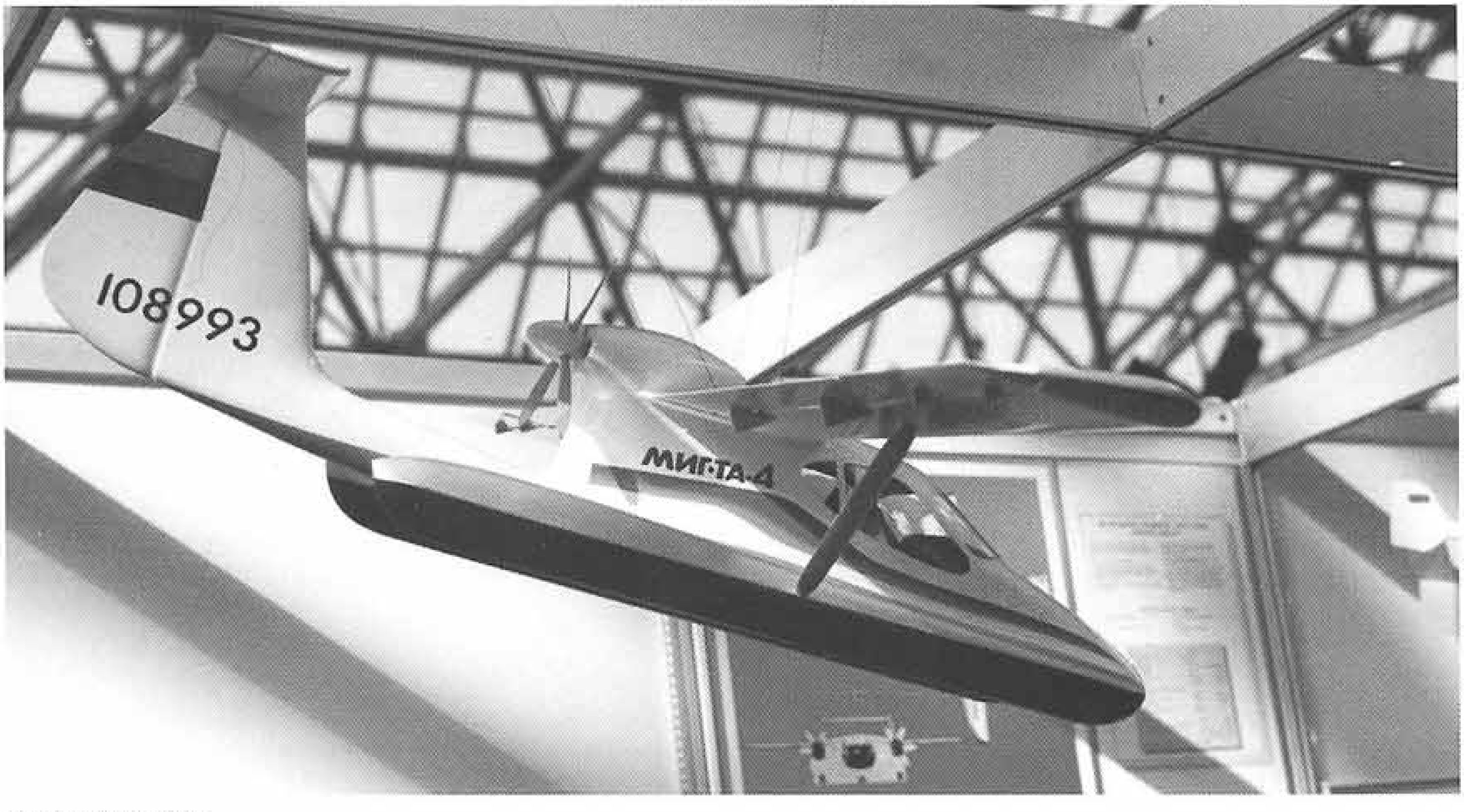
Span 11.0m (36ft 1in); length 12.1m (39ft 8⅜in).

Weight empty 3,320kg (7,319lb); maximum fuel 1,860kg (4,100lb); payload with maximum fuel 365kg (805lb); maximum takeoff weight 5,545kg (12,224lb).

Maximum cruising speed 870km/h (541mph); service ceiling 13,720m (45,000ft); range (4 passengers, 45min reserve) 3,970km (2,467 miles); takeoff run 980m (3,215ft; landing run 775m (2,543ft).

TA-4

Project in partnership with AKS Transal to carry pilot, three passengers and baggage from any surface, using air-cushion landing gear. Configuration as drawing, mainly composite airframe, US-supplied engines (300hp Teledyne Continental IO-550



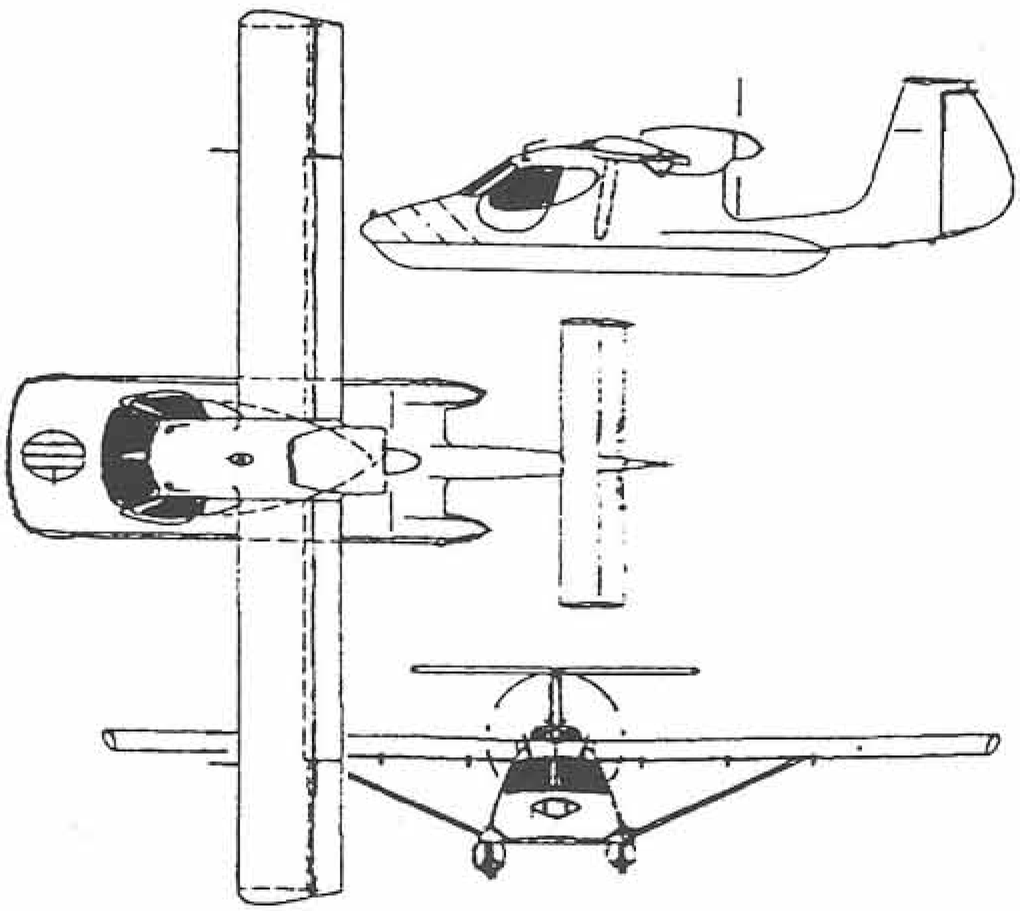
TA-4 model. (RART)

for propulsion, 48hp Nelson N-63P for air cushion) and avionics (Bendix-King). Was to have flown in 1994.

Span 12.4m (40ft 8¼in); length 9.054m (29ft 8½in).

Weights: internal fuel 130kg (287lb); loaded 1,740kg (3,836lb).

Maximum speed 270km/h (168mph); cruising speed 180–200km/h (112–124mph); service ceiling 4,000m (13,125ft); range 1,000km (621miles); takeoff speed 100km/h (62mph); takeoff run 415m (1,360ft); landing speed 100km/h (62mph); landing run 255m (836ft) on land, 305m (1,000ft) on water.



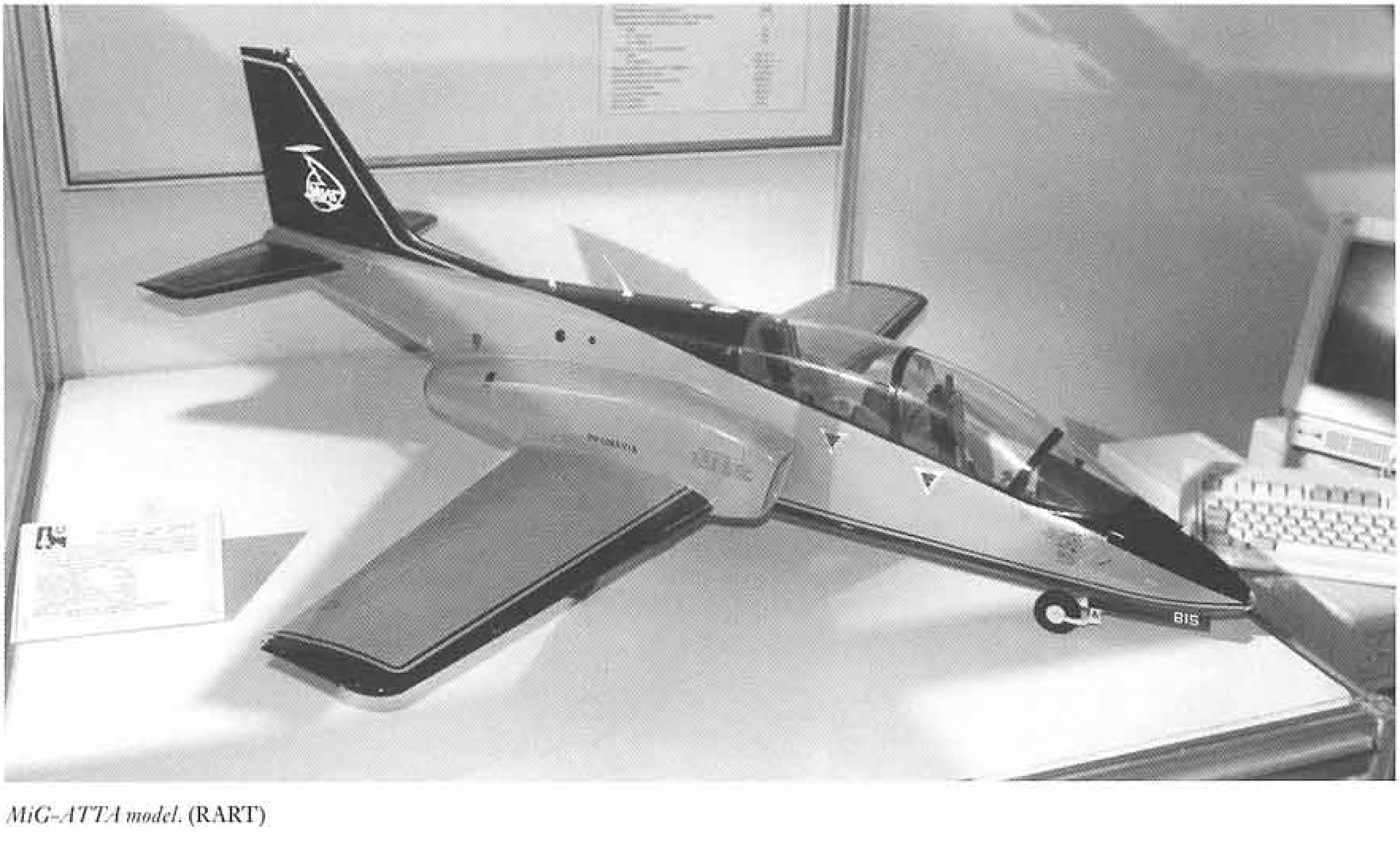
TA-4.

ATTA

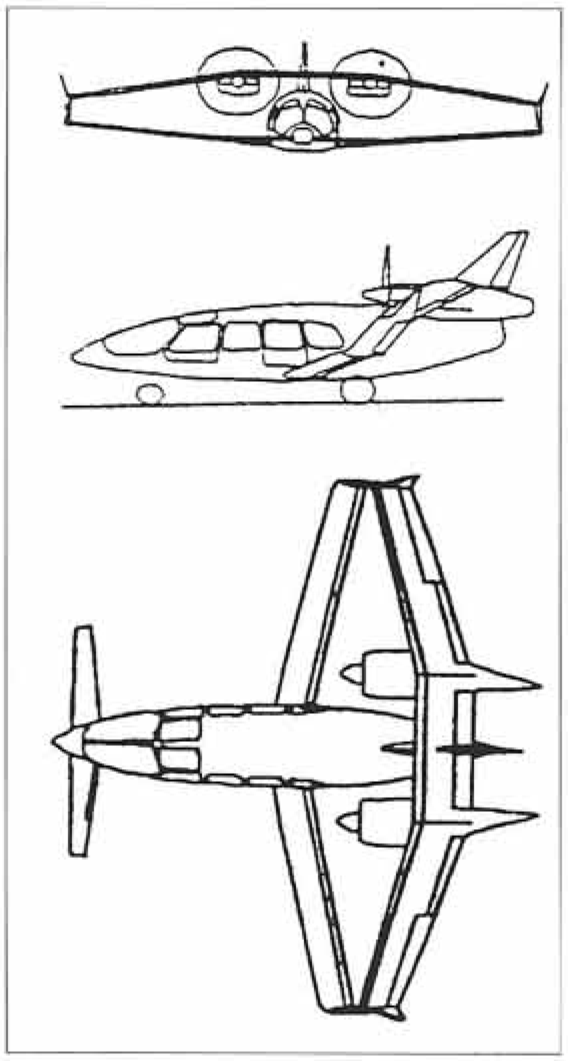
Light jet trainer based on Belgian Promavia Squalus but modified for twin engines (Williams Rolls FJ44 suggested). Details published and model exhibited but project shelved.

Stalker

This is a project by the KBESS (design bureau for experimental aeroplanes), formed by ANPK Mikoyan in partnership with CAHI and the engine research organization VIAM. It would have an unusual diamond configuration with a narrow-chord sweptback wing joined at the tip to a swept-forwards rear wing at a higher level, with in addition a controllable foreplane. Engines might be two 215hp AlliedSignal (Lycoming) TIO-360, fed with 530 litres (116.6gal) of fuel, and avionics



MiG-ATTA model. (RART)



KBESS Stalker.

would be Bendix-King. It would seat six, or carry 590kg (1,301lb) of useful load. Funds have not yet been committed to build a prototype.

Span 10.3m (33ft 9½in); length 7.25m (23ft 9½in); wing area 14sq m (150.7sq ft).

Weight empty 1,100kg (2,425lb); weight loaded 2,310kg (5,093lb).

Maximum speed 530km/h (329mph) at 4,000m (13,123ft); cruising speed 290km/h (180mph) at 4,000m, 350km/h (217.5mph) at 7,000m (22,966ft); range, up to 5,000km (3,107 miles); takeoff speed 135km/h (84mph); landing speed 128km/h (79.5mph).

Guided Missiles

It was part of the ethos of the Soviet Union never to miss a trick where weapons were concerned. Germany's use of guided missiles in the Second World War was a shock, and each of the new types of weapon – various tactical missiles, the V 1 cruise missile and the V 2 ballistic missile – soon had Soviet versions and derivatives. Most of these new weapons were assigned to specially created design bureaux, but, because they were basically like small jet aircraft, cruise missiles were also assigned to established aircraft OKBs, including MiG, Tupolev and Lavochkin.

The MiG OKB formed a special missile department which, for security purposes, was simply known as Set of Themes B. The titular head was Mikoyan's partner, Gurevich, but the chief designer was A Ya Bereznyak, who in 1939–43 had been famous for the BI-1 rocket-engined interceptor. This team was the first to get a missile into service. Except for the K-9 air-to-air missile, all the MiG-developed weapons were primarily for use against naval targets, especially surface warships of over 1,200 tons. They were carried into action under heavy aircraft of the A-VMF (naval air force).

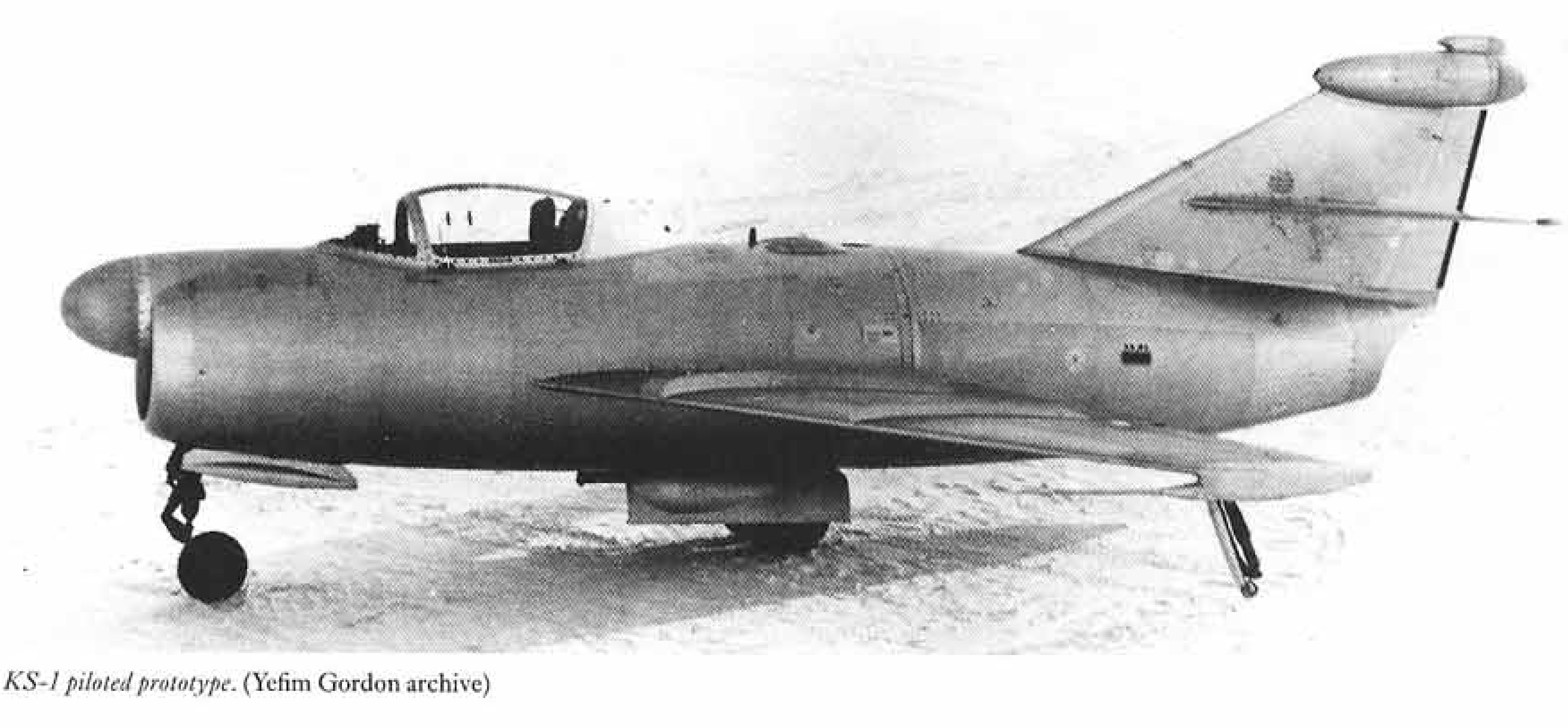
KS-1 *Komet*

This turbojet-engined cruise missile was ordered to be developed in late 1947, primarily as an antiship weapon to be launched by the Tupolev Tu-4. Versions were also to be developed for air-to-ground use, as well as versions launched from the ground. At the outset this missile, *Izdeliye* KS, was a joint project by the MiG OKB and SB-1 (special bureau No. 1). The chief missile designer of SB-1 was P N Kuksenko, but the head of the bureau was Sergo Lavrentyevich Beria, son of a formidable member of the Politburo who briefly succeeded Stalin.

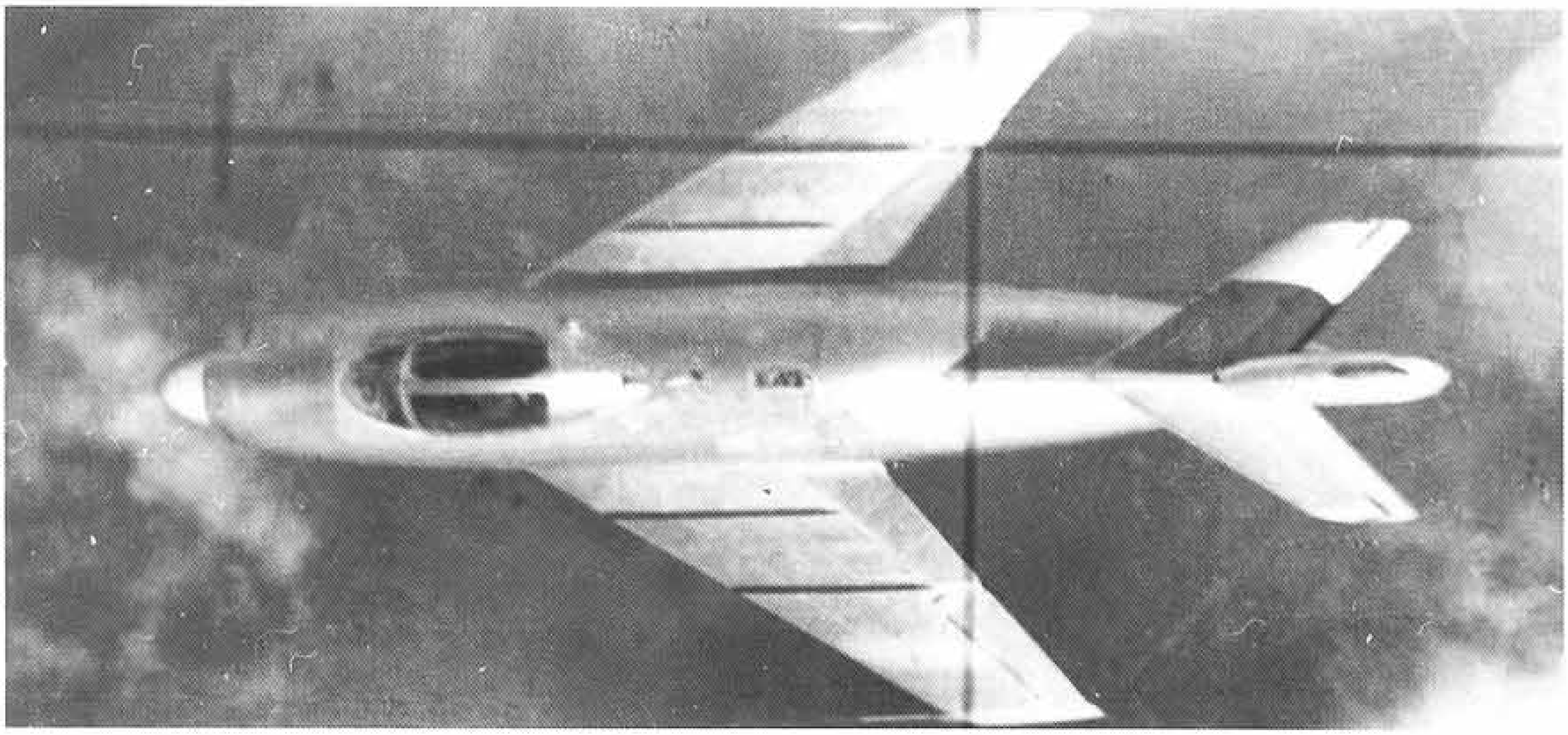
To reduce risk, the initial project resembled a small version of the S (MiG-15), though the RD-20 engine was fed by an inlet under the fuselage. The structure was conventional duralumin; the fuselage was to have a diameter of 1,145mm (45in) and length of 7.5m (24ft 7¼in), and the midmounted wing was to have a sweepback of 35° along the ¼-chord line (the same as the MiG-15) and span of 6.23m (20ft 5¼in). Launch weight was calculated at 2,600kg (5,732lb).

The Tu-4 was intended to carry one missile under the port wing or one under each wing. It was to launch the missile from an altitude of about 4,000m (13,123ft), from where the missile was to cruise on its AP-23 autopilot until its K-type radar detected a target. With a fuel capacity of 210 litres (46gal) the range was expected to be 195km (121 miles).

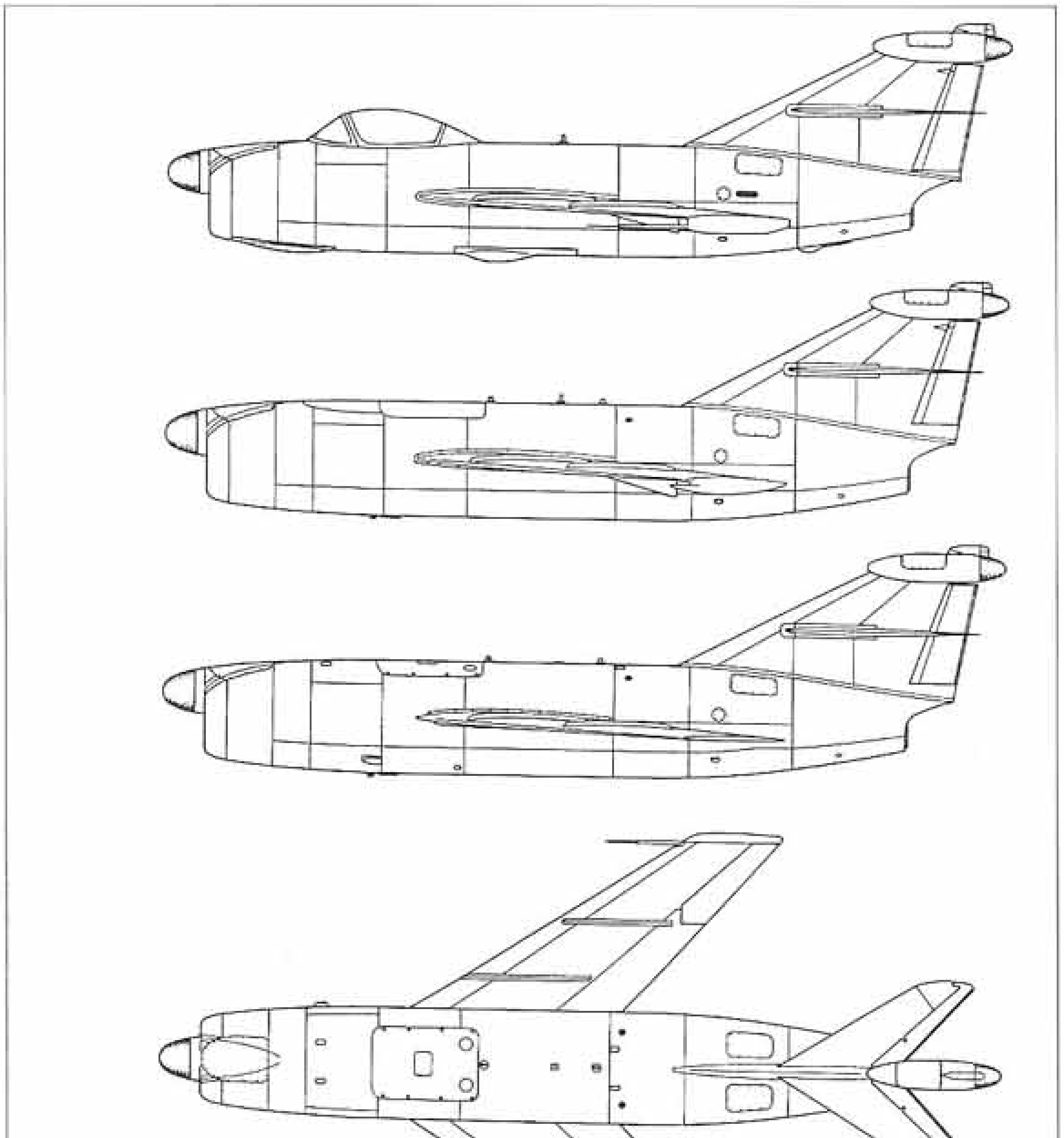
The project study was finished on 30 November 1948, and with S L Beria's political power a quick success seemed certain. Unfortunately once serious engineering design began in 1949 many changes were found to be necessary. The engine installation was



KS-1 piloted prototype. (Yefim Gordon archive)



Piloted KS-1 prototype photographed from Tu-4K. (Yefim Gordon archive)



From the top: Izdeliye *K (piloted analog); KS-1 prototype; three-view of Series KS-1.*

unsatisfactory, and in any case a better engine choice was the Rolls-Royce Derwent, which was coming into production in the USSR as the RD-500. This was much lighter, far more reliable and gave nearly double the thrust. A new propulsion system was schemed, with an RD-500K engine (with a simplified fuel and control system) fed from an inlet in the nose under the radar like the MiG-15 night fighter.

The lighter engine was one reason why the wing had to be moved forwards, and the designer then decided to be bolder and increase the ¼-chord sweepback to 55°, which also had the effect of reducing the span. This new wing was fitted with conventional ailerons and two fences. Meanwhile, the guidance system was refined. The target was first detected by the radar of the carrier aircraft, which tended to reduce the range at which ships could be engaged. After launch the missile was to be guided by radio command, using an aft-facing transmitting/ receiving antenna in a pod carried on top of the fin. This helped the autopilot to set the correct course. Later the missile's nose radar was to pick up the carrier aircraft's radar signals reflected from the target. Nearer the target the missile's own transmitter would become active, with target reflections received by antennas on the wing leading edge. This system was initially tested on an Li-2 (DC-3 derived) transport, and later on the *Izdeliye* FK (MiG-9L) aircraft described earlier.

On 25 March 1949 a government directive ordered the construction of a manned version of the missile. At this time it was considered that this was the only way to make such a complex guidance system work reliably. Designated *Izdeliye* K, the piloted version had a small cockpit with a jettisonable canopy and ejection seat in place of the warhead. The landing gear was of the bicycle type, with twin mainwheels with 500 × 180mm tyres, a single steerable nosewheel 370 × 160mm tyre, and small outrigger wheels at the wingtips. Other equipment included simple landing flaps, a braking parachute, RSI-6 radio, a KI-13 compass and flight instruments, an ordinary RD-500 engine with a manual control system (the missile was to have an RD-500K with fixed thrust), flight data recorders and an SPU-14 intercom linked to the carrier aircraft.

The first piloted vehicle, K-1, was first released from the carrier aircraft on 4 January 1952, the pilot being the courageous and experienced Sultan Amet-Khan. Four of these aircraft were built by the OKB, K-1 to K-4, but only the first three were equipped with cockpits. K-4 was eventually modified into the first true KS-1 missile. The empty weights of these piloted vehicles were typically close to 2,068kg (4,559lb), the engine was an RD-500 fed by 284 litres (62.5gal) of fuel, and gross weights were 2,453, 2,537 and 2,550kg (5,407, 5,592 and 5,621lb), respectively. The K-1 to K-3 had a maximum level speed of 1,060km/h (659mph) and an approach speed just under 400km/h (248mph), touching down at 270–290km/h (168–180mph). They made 150 flights, almost all in 1952.

The pilotless versions began captive flight testing in May 1952 (possibly K-4 was first), and the first launch from a Tu-4K trials aircraft took place on 21 November 1952. On one of the first tests with a warhead, probably in 1953, the target was the famous cruiser *Krasnyi Kavkaz*, and (according to legend) the MiG designers and engineers were genuinely surprised when the missile struck the cruiser, penetrated the armour belt around the hull and detonated, destroying the ship.

Series production had already been ordered in November 1952, and deliveries to Service units equipped with the Tu-4K, initially in the Black Sea Fleet, began in May 1953. The Tu-4K had the *Kobal't* radar replaced by missile guidance radar, and each outer wing was fitted with a missile pylon (an example of this pylon is on view in the Monino museum, with a missile attached) and an internal tank for 115 litres (25.3gal) of kerosene to top up the missile tanks before release. Because of lack of aileron power, though the Tu-4K could fly with one missile, it had to take off and climb at low speed with two.

The production KS-1 was usually equipped with an FK-1 nuclear warhead which, like others in this class, was developed by special institute NII-6. With auxiliary systems, this warhead weighed nearly 1,000kg (2,205lb). Some missiles had armour-piercing conventional warheads weighing 500–800kg (1,102–1,764lb).

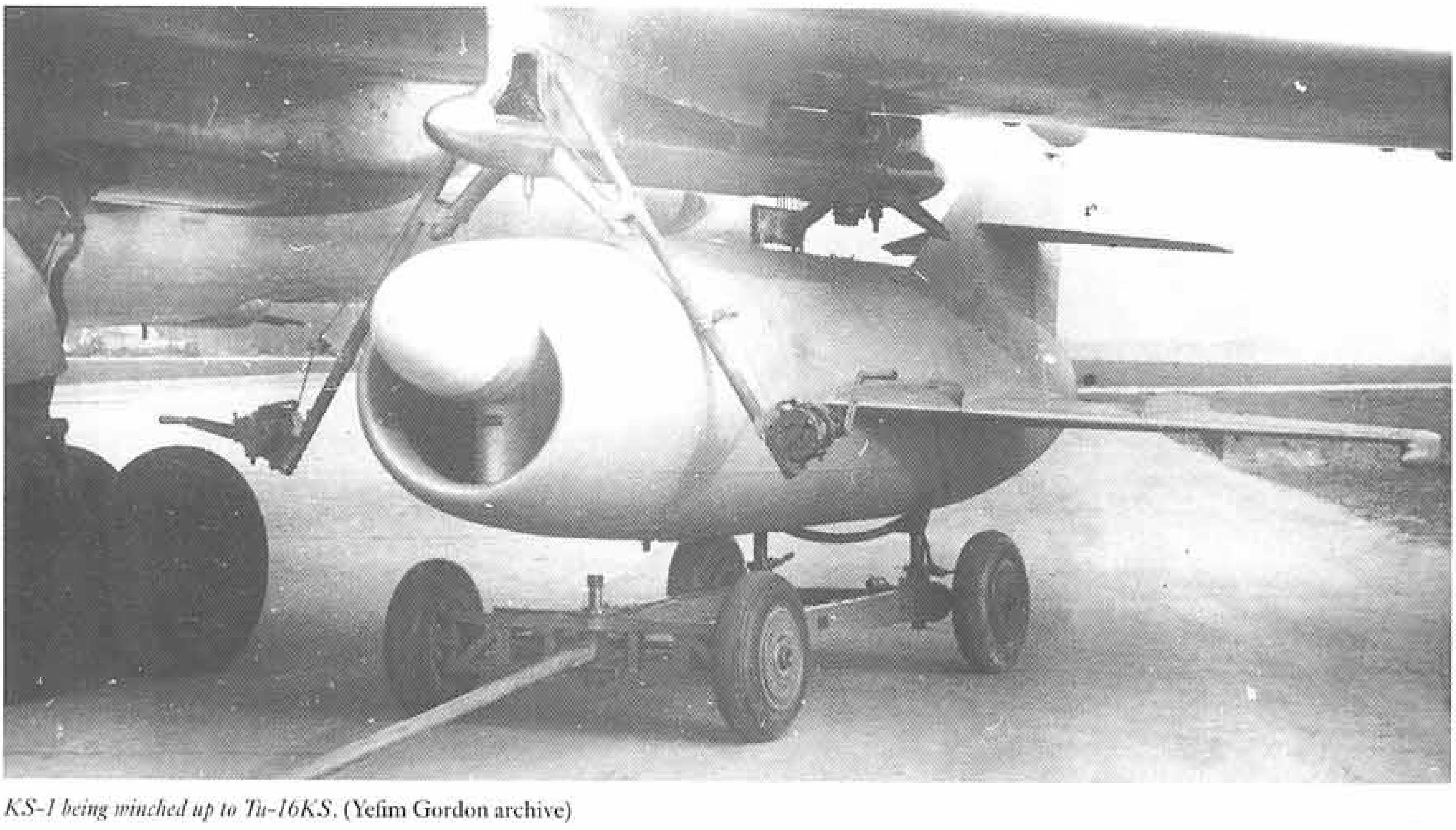
In 1953 the Politburo considered assigning the first fifty missiles to destroy the US Navy carriers operating off Korea. Agonizingly, the decision was taken to hold off, to avoid the possibility of the US starting a third world war. Only a few were built for Tu-4K regiments, which from 1955 were being re-equipped with more modern aircraft.

The missile continued in production, and more than 90 per cent eventually armed the Tu-16KS strategic jet bomber from 1955 until 1966. This again carried one missile under each wing, using a different pylon, forming part of *kompleks* K-87. In 1964–65 a batch of twenty-four used Tu-16KS, with their missiles, were transferred to Indonesia. The ASCC called this missile 'AS-1 Kennel'.

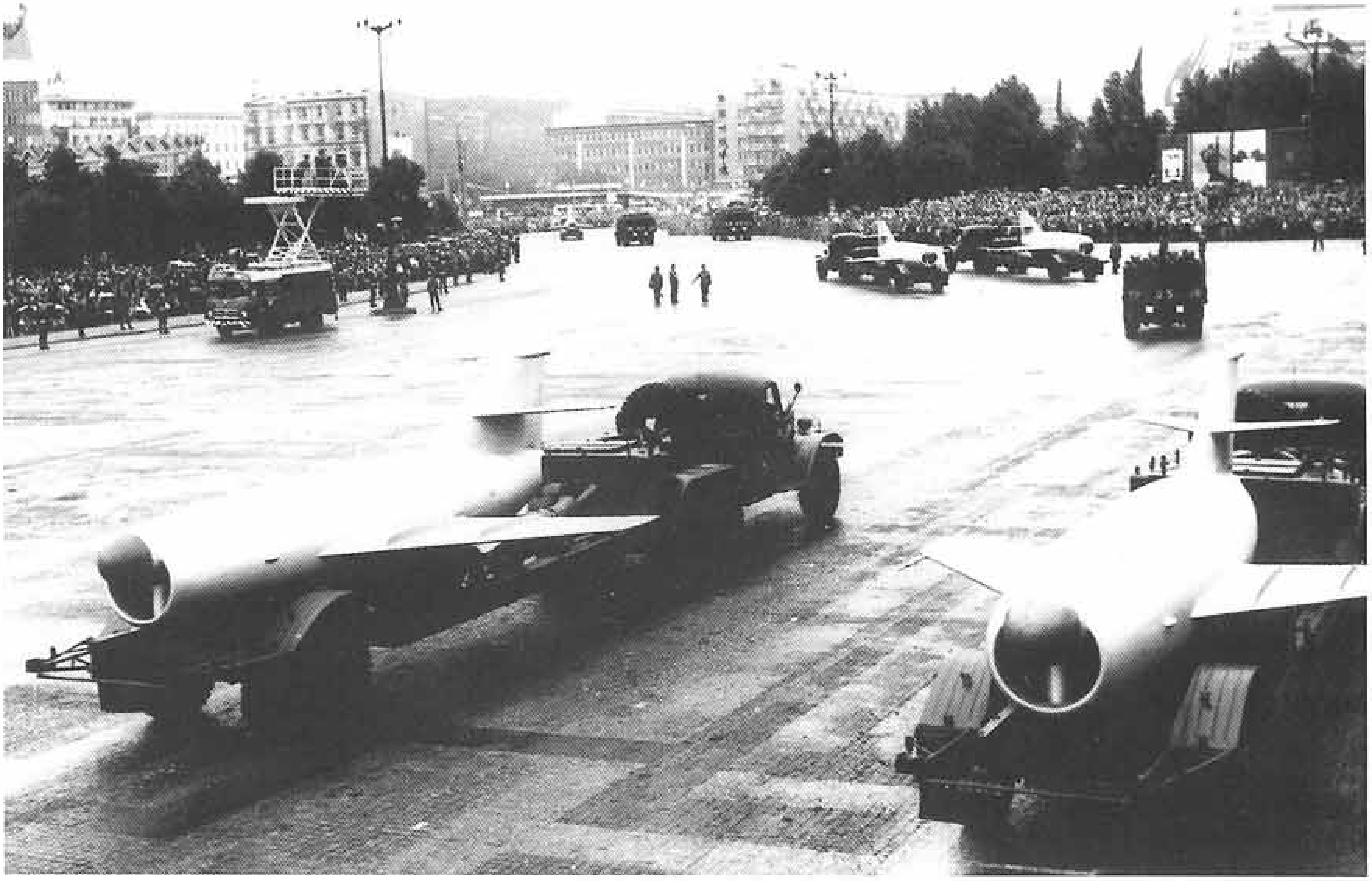
Span 4.722m (15ft 5⅞in); length 8.29m (27ft 2⅜in); wing area 4.02sq m (43.3sq ft).

Weight empty 1,920kg (4,233lb); weight at launch 2,735kg (6,030lb).

Cruising speed 1,060km/h (659mph) at 400m (1,312ft); range at low level (standard 320lit, 70.4gal tank) 80km (50 miles) launched from Tu-4K, 95km (59 miles) from Tu-16KS.



KS-1 being winched up to Tu-16KS. (Yefim Gordon archive)



Sopka *ground-to-ship missiles on parade in Warsaw*. (Yefim Gordon archive)

FKR-1

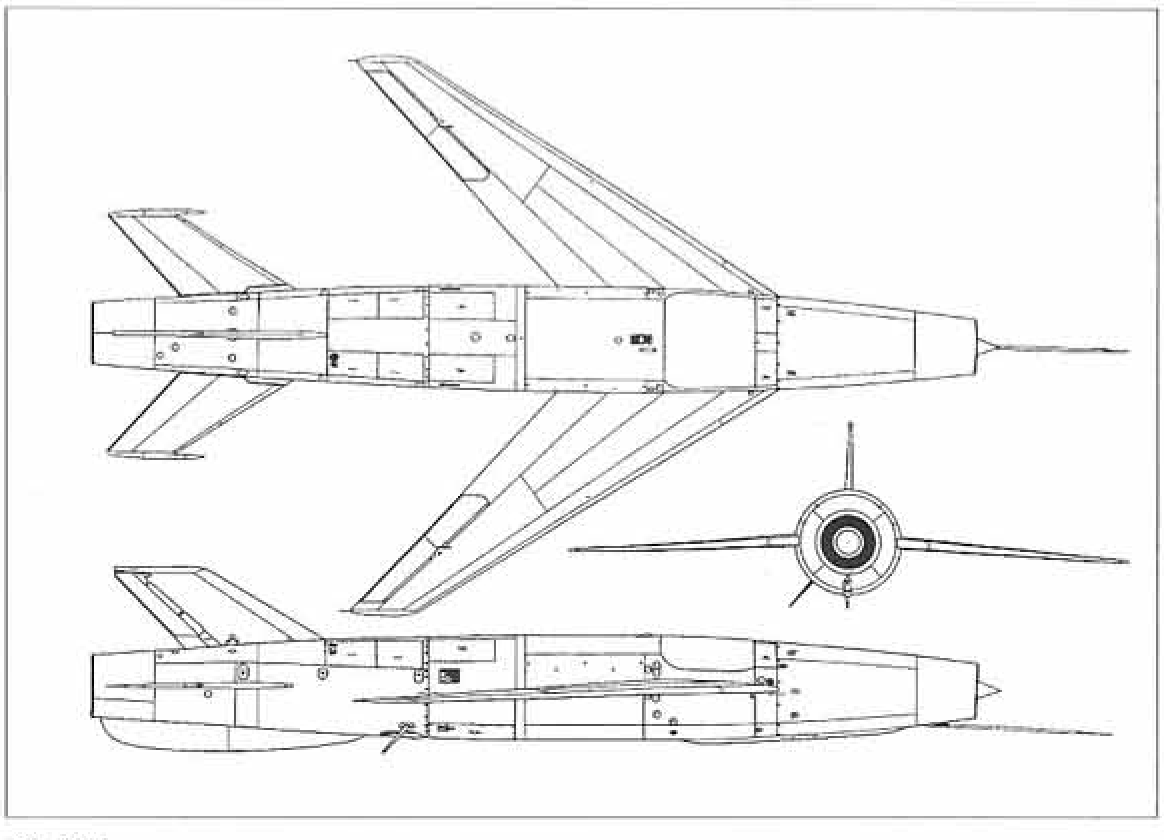
This was the designation of the *kompleks* of the first land-based version of the KS missile. The weapon was transported, elevated and launched from a ramp carried on a single-axle trailer articulated behind a standard six-wheel tug. The missile rested on a cradle with a launch rocket on each side. The only remarkable feature is that the missile had inertial guidance. Standard warhead yield was 500kT. It was deployed by ground forces units in 1954–59, receiving the ASCC designation 'SSC-2A Salish'. Data as before.

S-2 *Sopka*

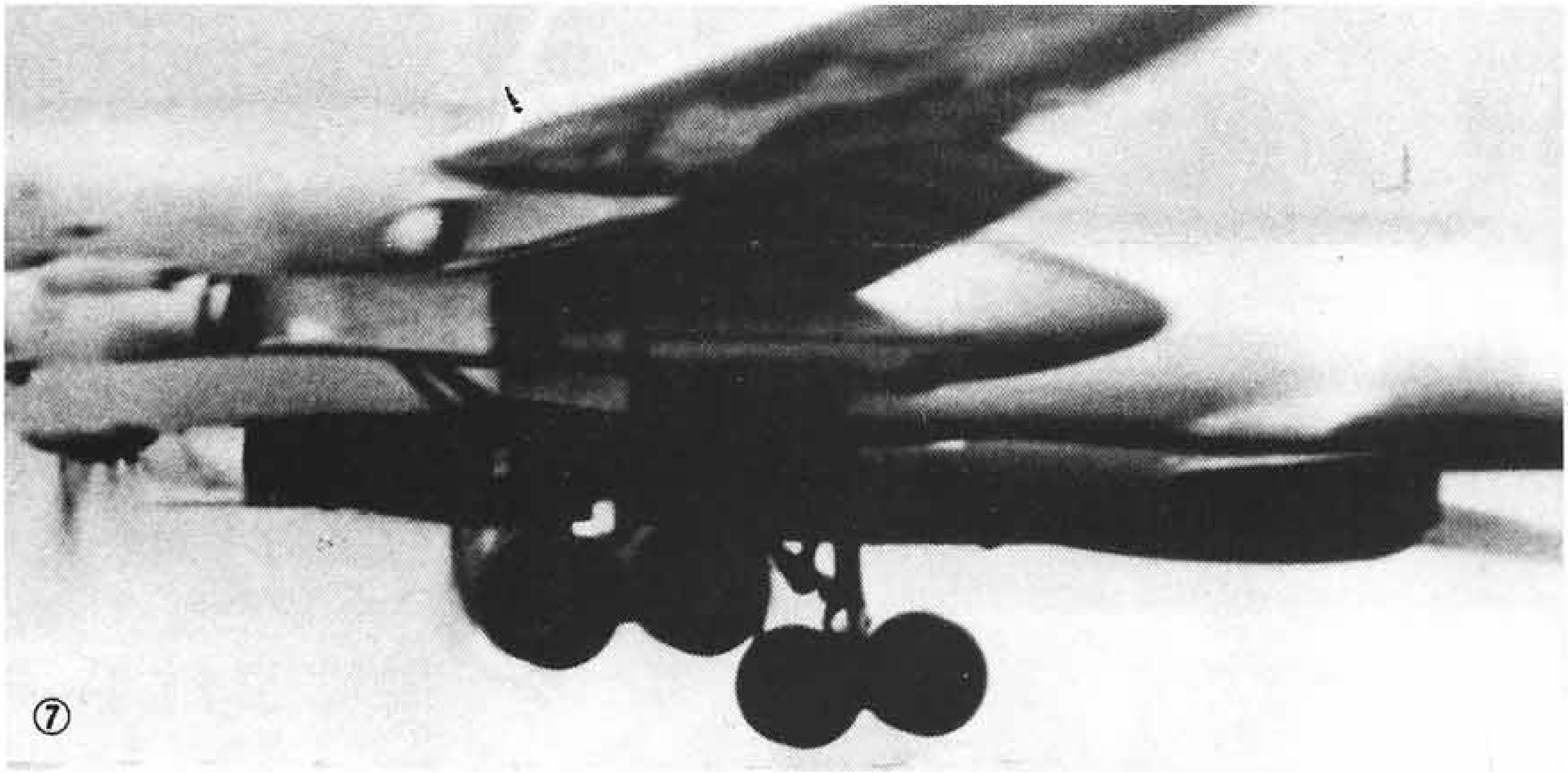
Also designated 4K87, this missile was a second land-based version of KS-1. Its name means a small conical hill. The missile was carried on a launch ramp totally unlike that in the FKR-1 system, comprising twin girders with a space between them for the passage of the single rocket boost motor attached under the missile's tail. The launcher was on a swivelling mount on a four-wheel base (stabilized by outriggers screwed down before launch) towed by a separate tug. Guidance was by radio correction by the fire unit followed by active radar homing. S-2 was deployed by naval coast-defence forces of the USSR, Poland and possibly the German Democratic Republic. Data as before. The ASCC name was 'SSC-2B Samlet'.

Kh-20

One of the largest weapons ever carried by any aircraft, this cruise missile was requested by the Council of Ministers in 1953. Its size was in order to meet the combined requirements of long range and a heavy thermonuclear warhead. Such a missile was made possible by the lifting capability of the Tupolev Tu-95, which also had adequate ground clearance for loading this weapon. From the outset a specially developed version of this aircraft was envisaged as the principal



Kh-20M.



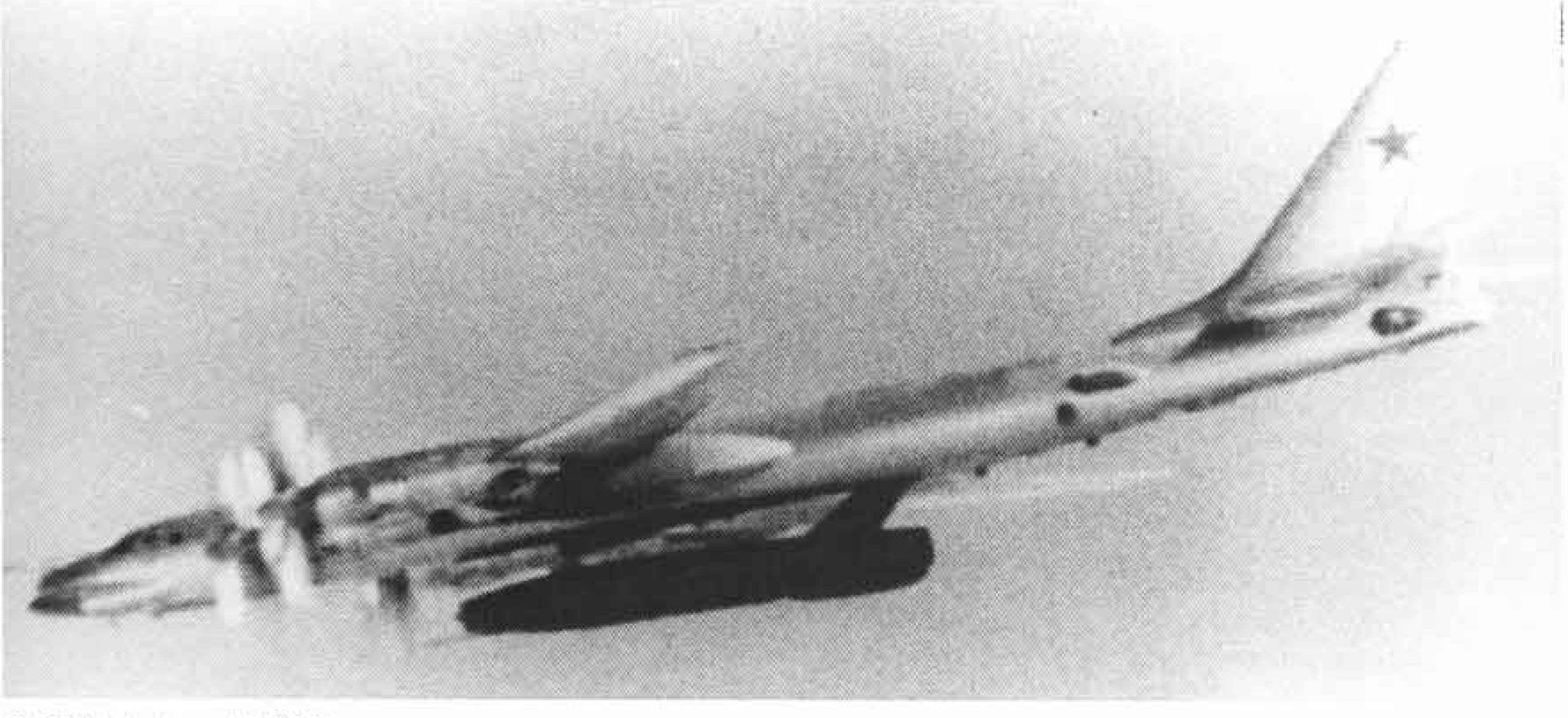
Tu-95K taking off. (RART)

carrier aircraft, and in the event it was to prove the only one.

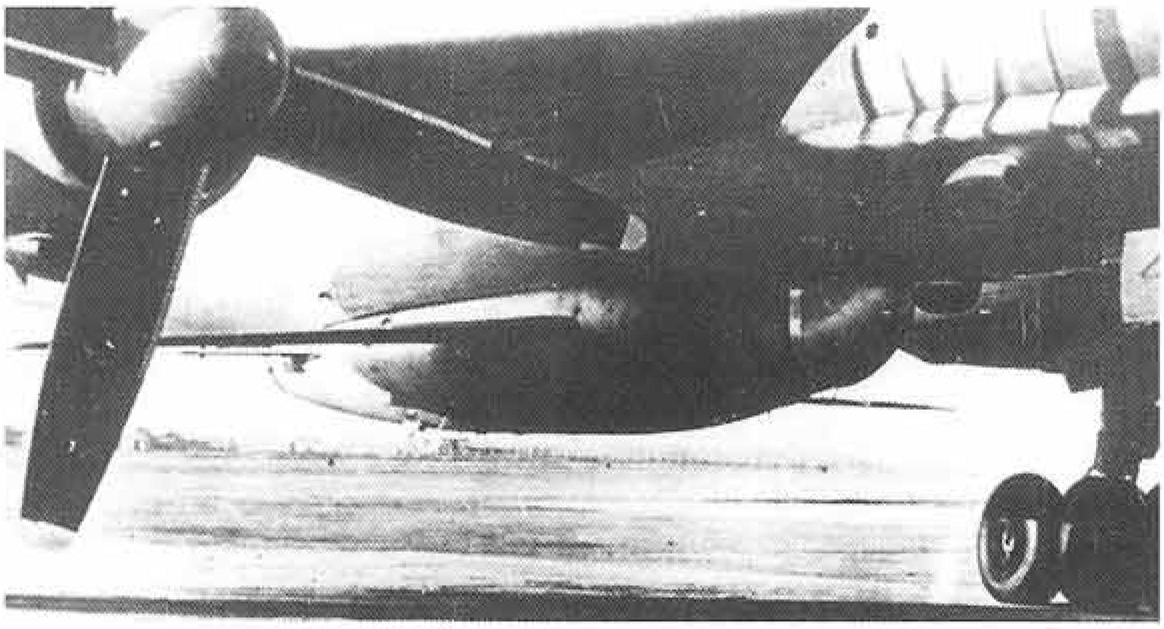
The Kh-20 was the main element in a *kompleks* designated K-20. It was the first long-range supersonic-cruise winged missile, and to this day no other air-launched weapon has carried a more devastating warhead. The Kh-20 was also the first major project of the special missile department set up wholly within the MiG OKB under Gurevich and Bereznyak, without involvement by SB-1.

As the drawing overleaf shows, it used almost the same wing and tail as the contemporary fighters, such as the I-370 (I-1), though of course without landing flaps and with a structure designed to a reduced load factor (because the missile was not expected to indulge in combat manoeuvres). The engine was a centrifugal turbojet, believed to be a nonafterburning version of the Klimov VK-7 rated at 4,000kg (8,818lb) at sea level. This engine was considered to be best able to meet the challenge of unfailingly starting after a long soak at high altitude under the carrier aircraft. It just fitted in the 1.705m (67.13in) diameter of the fuselage, and was fed by a circular nose inlet with a fixed conical centrebody. The engine was surrounded by panels secured by countersunk screws, and could be changed by unbolting the rear fuselage.

The initial flight tests of the carriage and release system, and subsequently of the complex guidance and control network, were done with modified MiG-19s (*see* SM-20, SM-20P, SM-K/1 and SM-K/2), launched at high altitude from a Tu-95K trials aircraft. Test flights of Kh-20 prototype missiles took place from 1957. The initial Kh-20 production version was built in limited numbers for the interim Tu-95K. The main version was the Kh-20M, with increased fuel capacity. This was cleared for operational use in October 1959. The carrier



Kh-20M being dropped. (RART)



Kh-20 missile loaded under Tu-95K. (Yefim Gordon archive)

aircraft was the Tu-95KM, followed from 1961 by the flight-refuelled Tu-95KD, most of which were the original carrier aircraft after modification. These aircraft were distinguished by the fact that the glazed nose of the original bomber was replaced by a very large *Krypton/Rubin*-N radar with unprecedented ability to detect and track distant ship targets.

The missile was winched up into a recess under the carrier aircraft, with its highly swept fin inside the fuselage and the nose behind a hinged fairing. The aircraft's fuselage was considerably rearranged so that a special crew could operate the radar and manage the missile. At the appropriate distance from the target, and at a height much greater than that adopted for the KS-1, the nose fairing would be rotated up out of the way and the missile engine started using the carrier aircraft's electrical power and a special supply of volatile petrol to initiate combustion. During the prelaunch checks the Tu-95's tanks would keep feeding those of the missile. Final target information would be passed to the missile via an umbilical cable.

After release, the Kh-20M cruised on its own inertial system, but with corrections from the parent aircraft's enormous radar passed via a blade antenna projecting diagonally from the missile's rear fuselage. The missile would finally dive on its (high-value) target, detonating the warhead, which in all operational versions was nuclear, with a yield of 1 MT. The ASCC called this missile 'AS-3 Kangaroo'.

Span (Kh-20) 9.15m (30ft), (-20M) 9.03m (29ft 7½in); length, without PVD boom, (-20) 14.96m (49ft 1in), (-20M) 14.603m (47ft 11in); wing area 25sq m (269sq ft).

Weight empty, not available; launch weight (-20) 8,950kg (19,730lb), (-20M) 11,000kg (24,250lb).

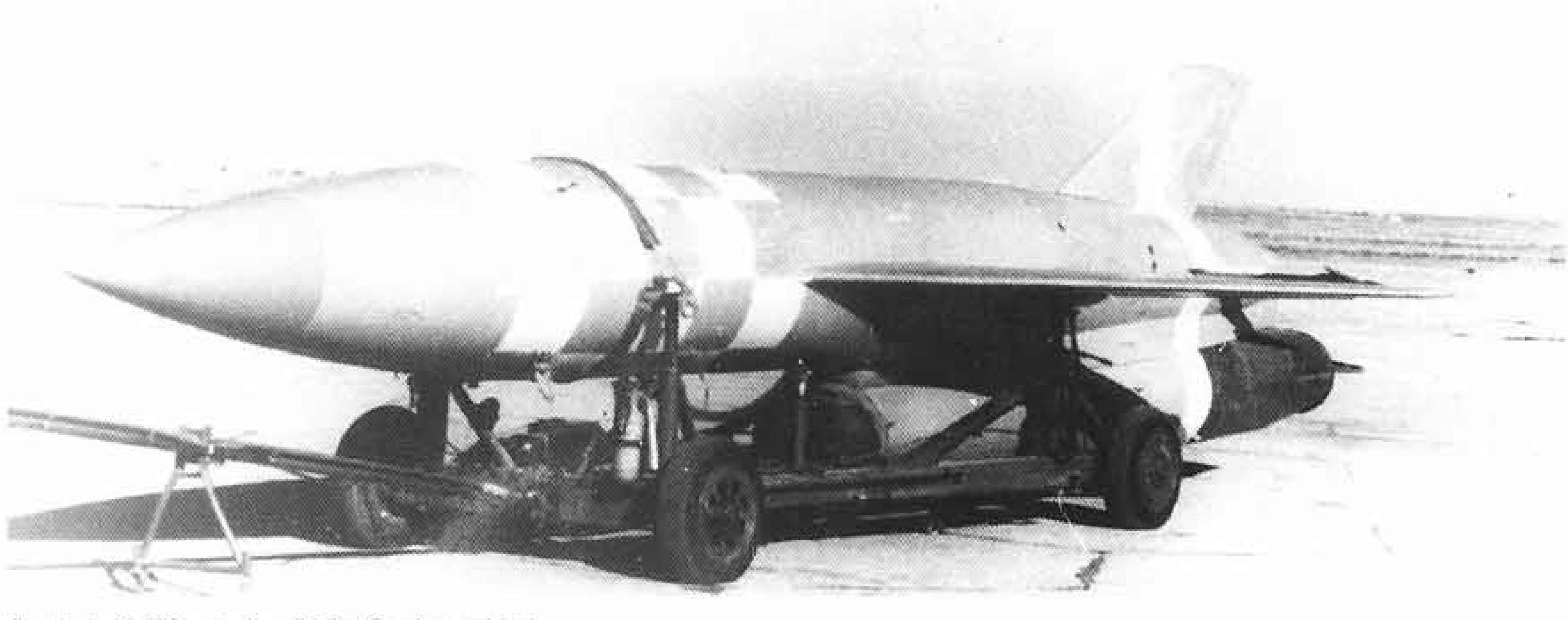
Cruising speed, up to Mach 2 (2,125km/h, 1,320mph); range (-20) 390km (242 miles), (-20M) 650km (404 miles) at Mach 1.8, 350km (217.5 miles) at Mach 2.

K-10S

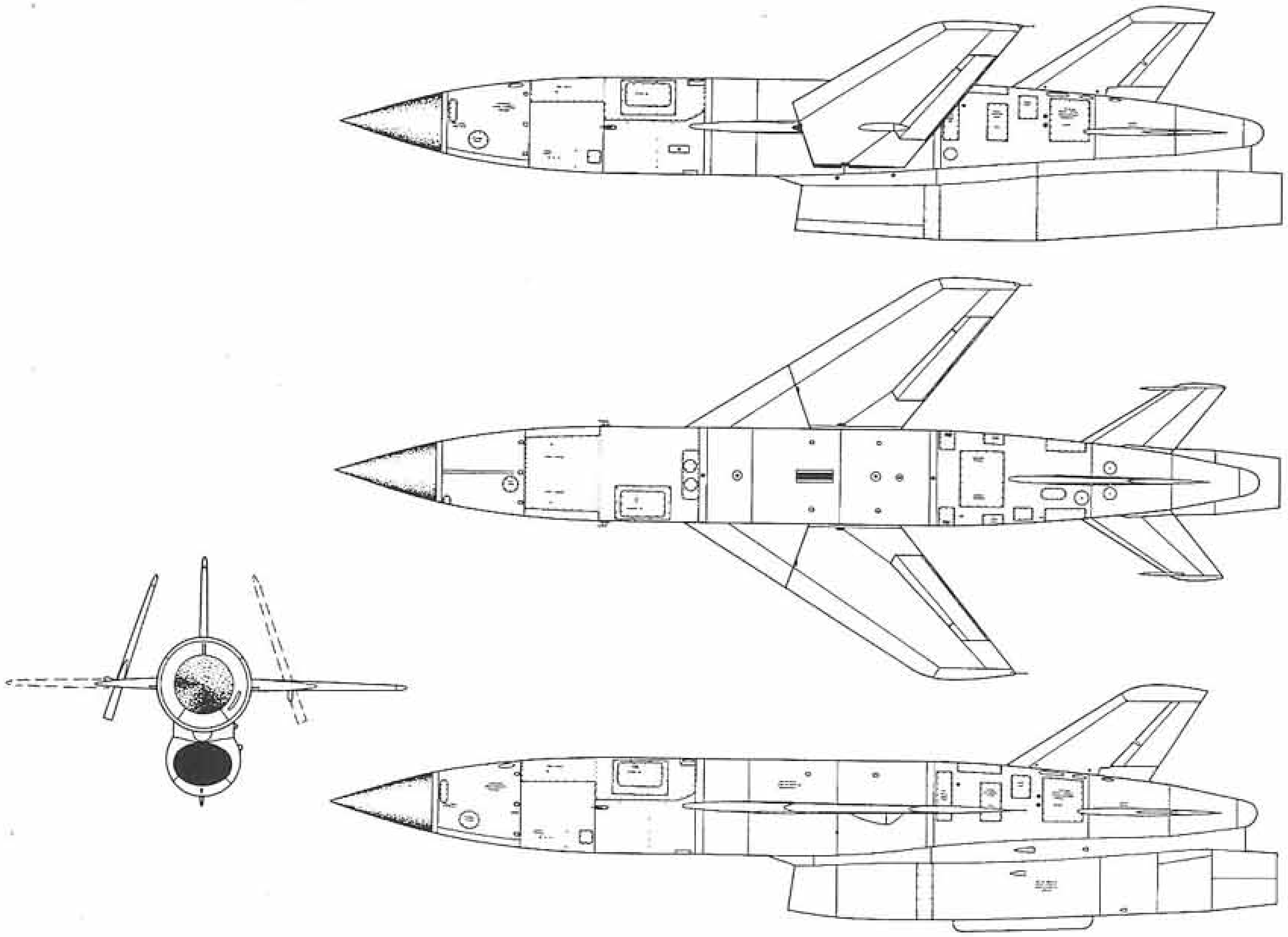
Though the KS-1 was adapted for carriage by the Tu-16 jet bomber, this aircraft really needed a more modern missile, able to carry similar warheads over greater distances at supersonic speed. Such a missile was ordered in 1955 from the Set of Themes B department, while the corresponding Tupolev design department worked on *kompleks* K-10, which included the SYeN target-acquisition and guidance radar and a pressure cabin next to the missile for the radar operator, who prepared the missile for launch. All this was packaged into the Tu-16K-10 carrier aircraft, which was equipped with one missile recessed underneath the fuselage.

The missile resembled a faster version of the original *Izdeliye* K, predecessor of the KS-1, in having the engine fed from an inlet underneath. In this case the engine, an M-9FK, a simplified constant-rpm derivative of the RD-9B fighter engine, was installed in a nacelle under the missile's rear fuselage, with its propelling nozzle behind the end of the missile body.

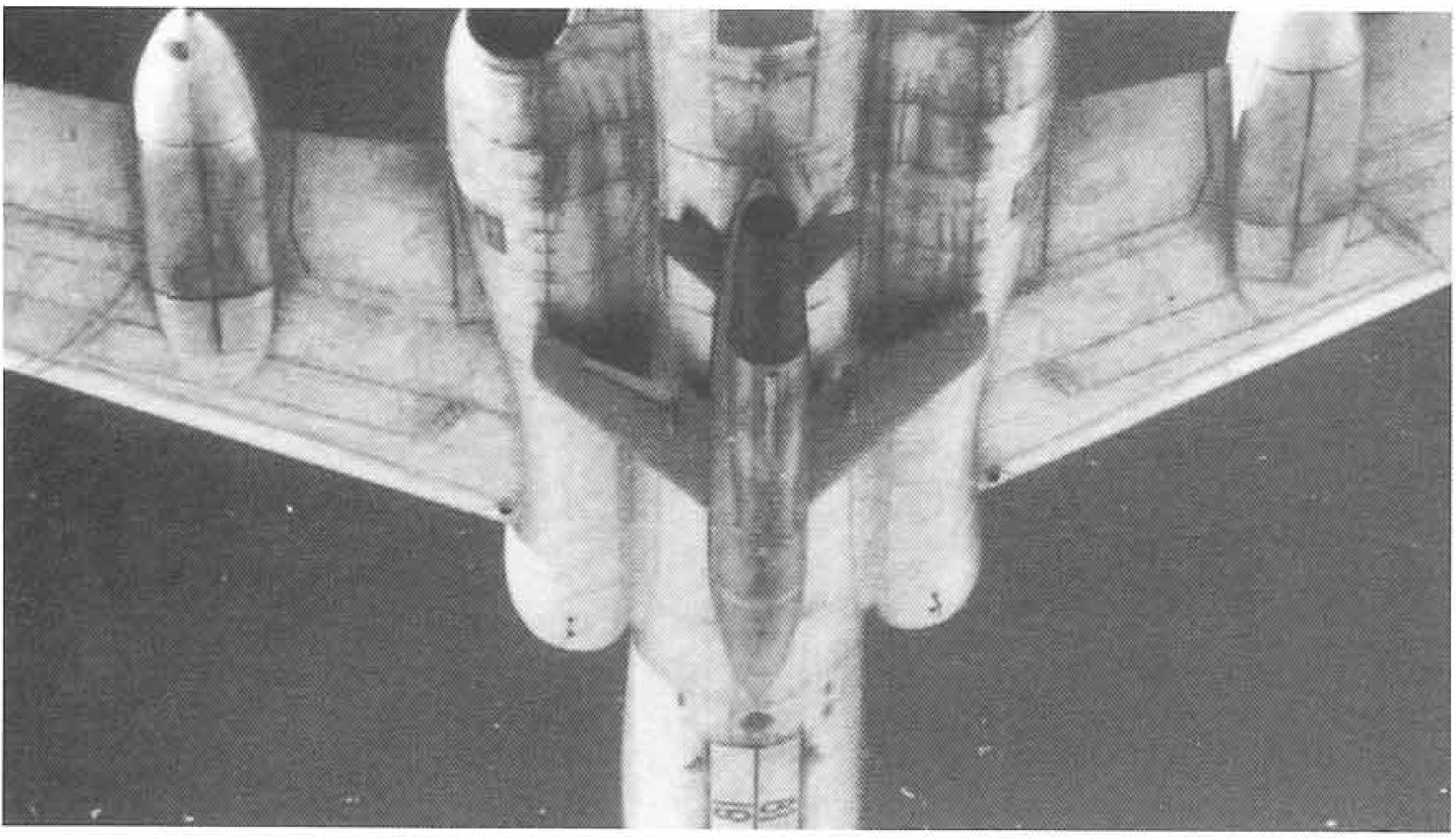
The fuselage was almost perfectly streamlined, and had a diameter of 1 metre (39.4in). At the front was a pointed conical radome over the missile's parabolic radar antenna, the radar itself being in the bay immediately to the rear which was hermetically sealed and thermostatically controlled. The next fuselage bay contained the FK-1M or FK-10 nuclear warhead; again there was also a version with an armour-piercing conventional warhead. The large third bay was made of steel and housed the 1,575 litres (346.5gal) of fuel. Finally came the electrical, hydraulic and



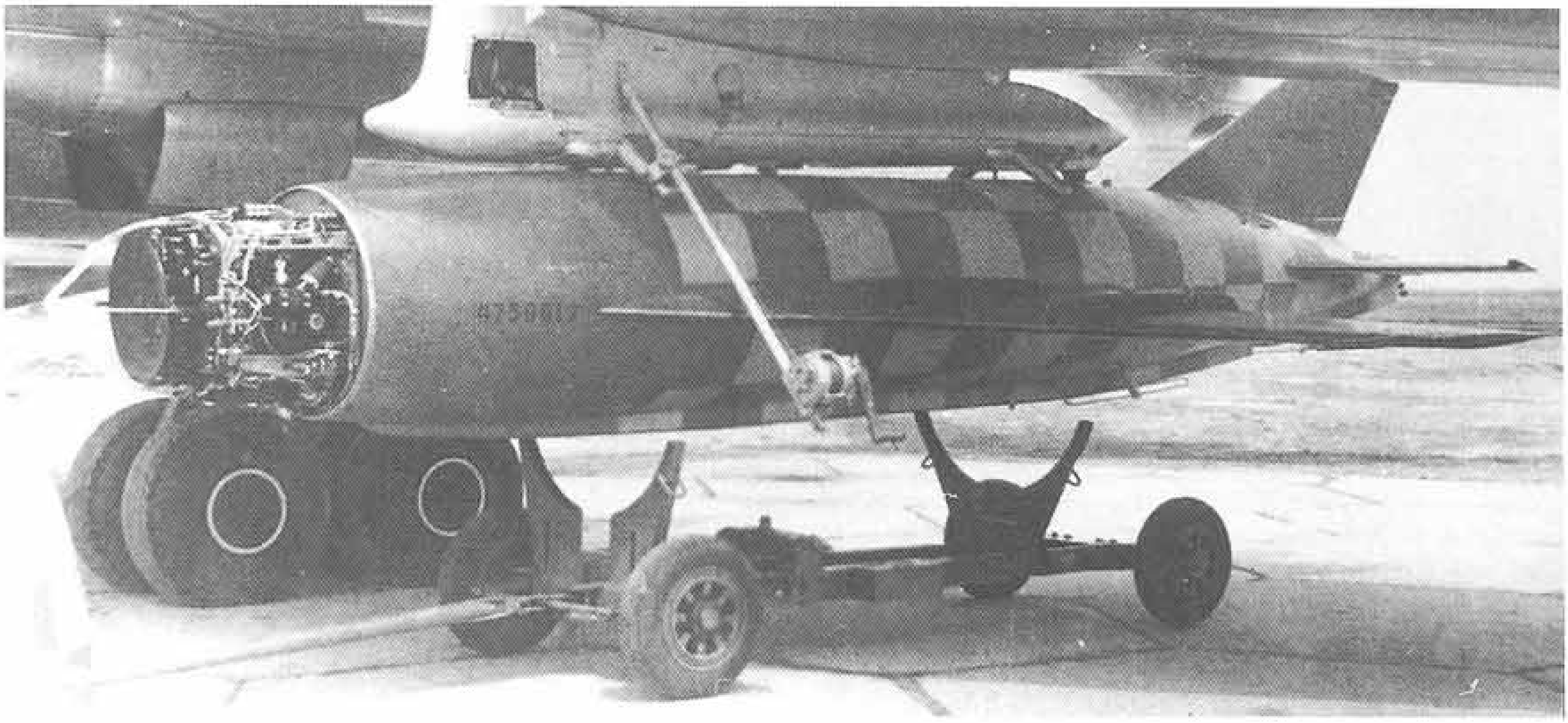
Prototype K-10S on trolley. (Yefim Gordon archive)



Three-view of Series K-10S, with lower side view of K-10SM or K-10SMB (same).



K-10S carried by Tu-16K-10. (RART)



KSR-2 prototype loaded under Tu-16KSR (radome removed). (Yefim Gordon archive)

other accessory systems with numerous access panels.

The rather stubby wings had a ¼-chord sweepback of 55°, and to ease transport and storage they folded on glove-vane spigots parallel to the longitudinal axis. The very small tailplanes were fully powered, with antiflutter rods at the tips, and the vertical tail, which was made of Elektron magnesium alloy, could be folded down horizontally.

The missile was carried by the Tu-16K-10 half recessed into the fuselage. Near the target it was lowered clear of the aircraft on a vertical powered pylon while the engine was started and final target information supplied. After release, guidance was initially by radio command, using a receiver antenna and radar beacon in the tailcone to pass information on the (usually moving) target from the carrier aircraft's SYeN radar. In the terminal phase, typically the final 40km (25 miles), the missile used its own radar.

The first Tu-16K-10 was built in 1958, a year after the start of K-10 flight testing. Production of the K-10S series version began in 1959, and the Tu-16K-10 was declared operational in October 1961, two years after the Tu-95KM. In the course of production the missile was upgraded to K-10SM and K-10SMB standard, both with improved engine installations for an R-11 turbojet, and possibly (though details are lacking) with a different radar. These upgraded missiles probably formed part of *kompleks* K-26, because they were carried on the centreline of the Tu-16K-10-26, which was produced in small numbers in 1962. This aircraft could alternatively carry two KSR-2 or KSR-5 missiles on wing pylons. The ASCC called all K-10 type missiles 'AS-2 Kipper'.

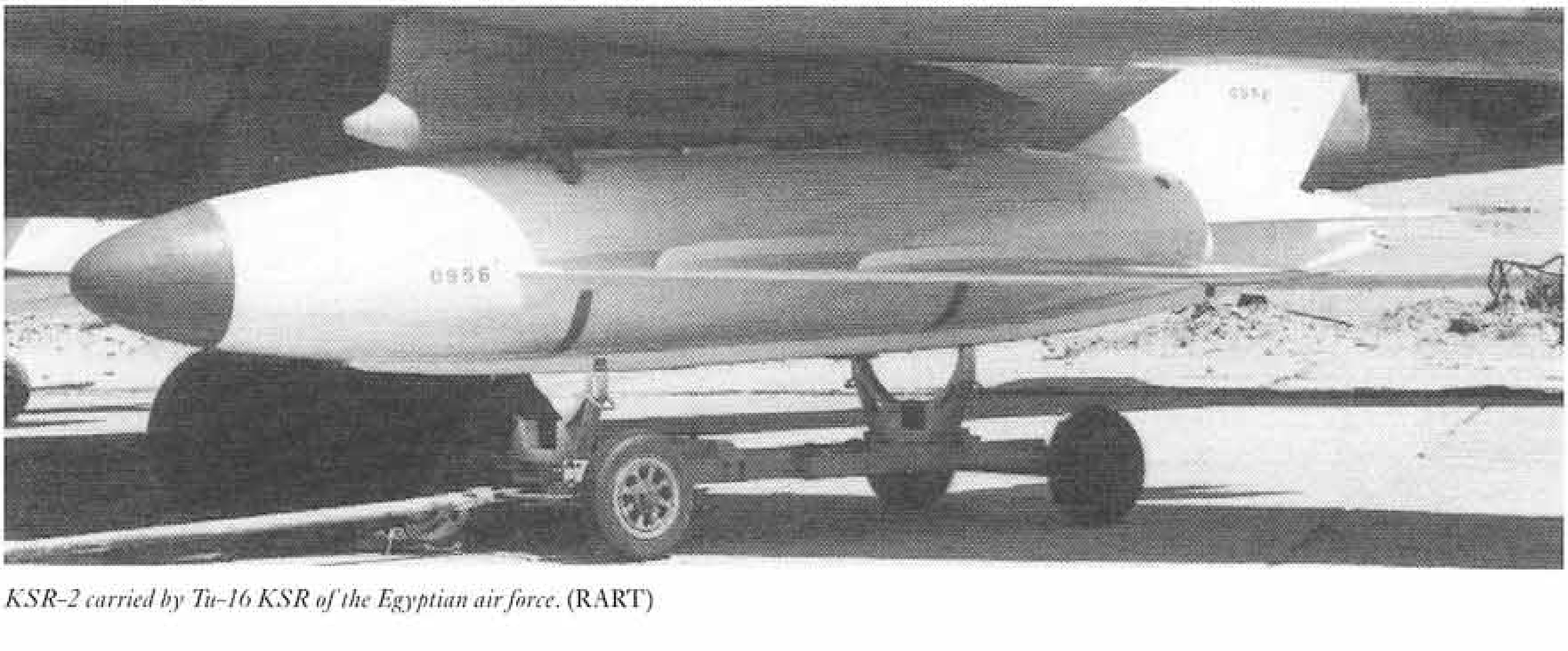
Span (prototypes) 4.6–4.88m, (K-10S) 4.18m (13ft 8½in); length (prototypes) 9.5–10m, (K-10S) 9.75m (31ft 11⅞in).

Weight empty (K-10S) 2,296kg (5,062lb); warhead 940kg (2,072lb); launch weight (typical prototype) 4,350kg, (K-10S) 4,533kg (9,993lb).

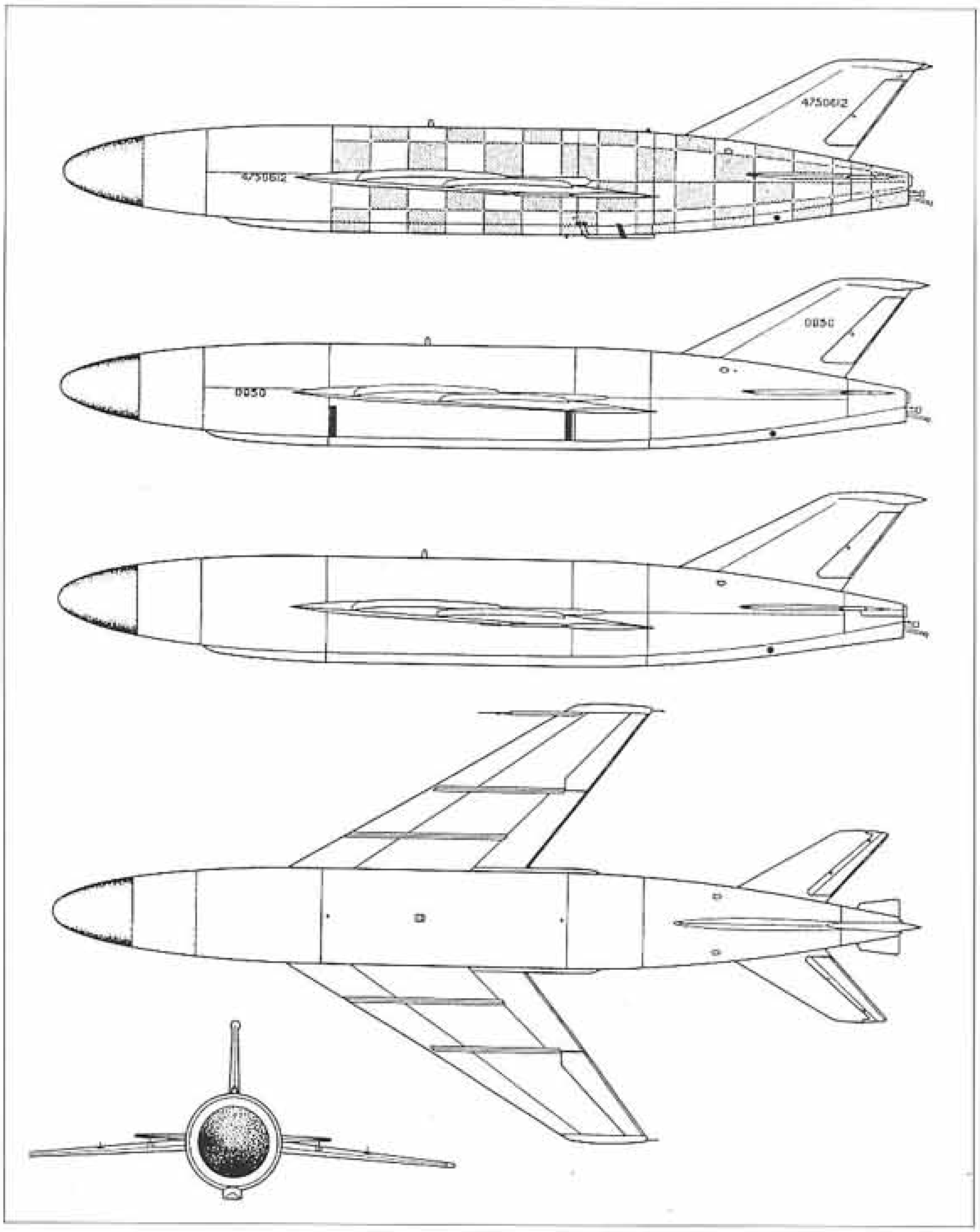
Performance of initial series K-10S: launch altitude 1,500–11,000m (4,921–36,089ft); cruise altitude 500–8,000m (1,640–26,247ft); cruise speed Mach 1.2 (1,275km/h, 792mph); closing speed in dive on target 2,030km/h (1,261mph, Mach 1.9); range (low level) 110km (68.4 miles), (high level) 325km (202 miles).

KSR-2, KSR-11

Last of the bureau's heavy cruise missiles, the KSR project was started by the Set of Themes B department in 1960. No longer located at the original



KSR-2 carried by Tu-16 KSR of the Egyptian air force. (RART)



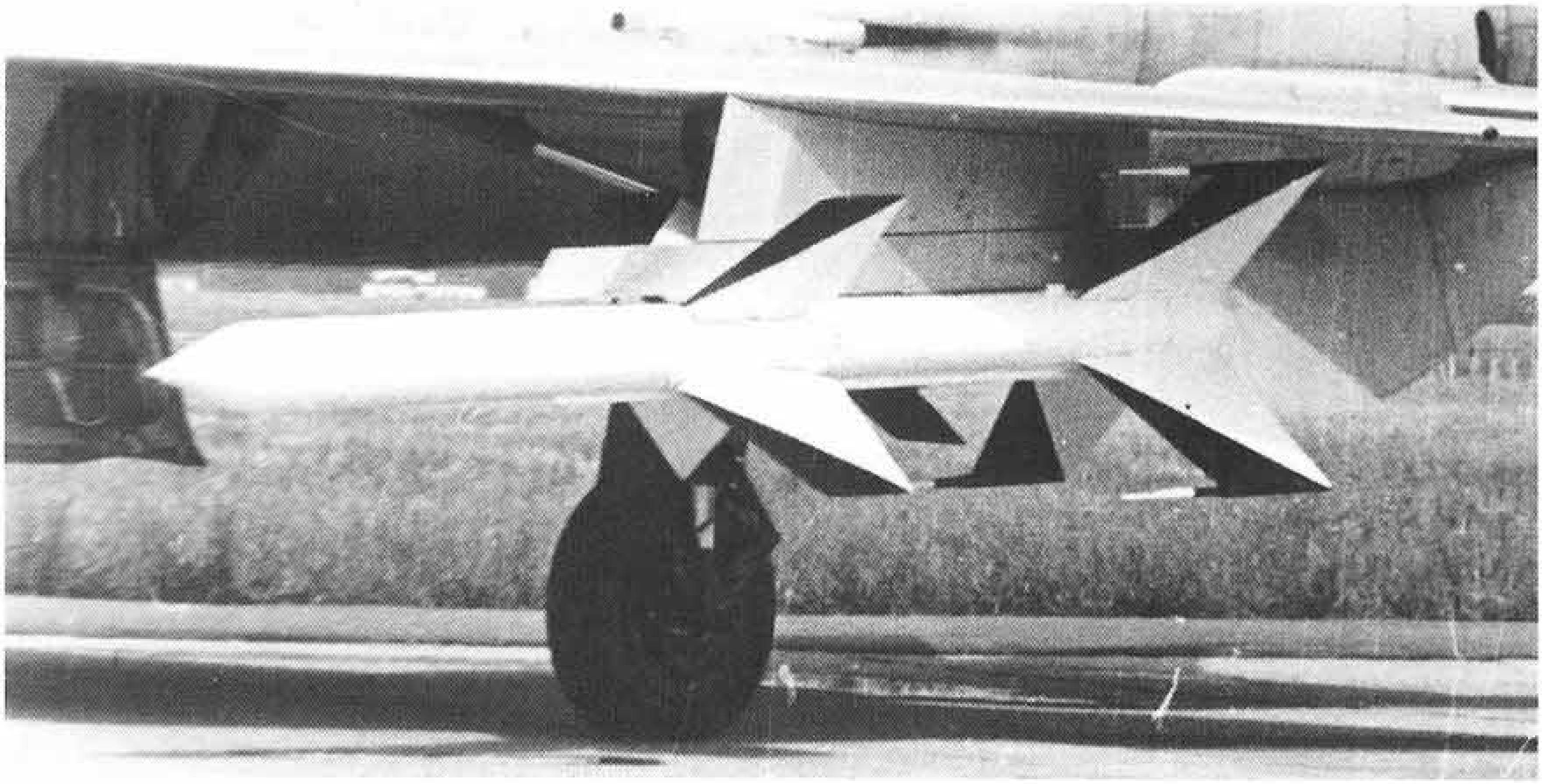
From the top: KSR-2 prototype; Series KSR-2; three-views of KSR-11.

site on the Leningrad Highway, this was by this time headed by A Ya Bereznyak. Later this department became a separate OKB, still headed by Bereznyak, named *Raduga* (rainbow). It built a great reputation for a succession of heavy attack missiles.

The KSR was an upgraded replacement for the primitive KS-1, able to be launched from the same pylon interface under the wing of a Tu-16. Both missiles had essentially the same airframe. Bereznyak's experience with rocket engines led to this new missile being powered by a liquid-propellant rocket, the S2-721V of 1,200kg thrust. Even more astonishing, the range was two to three times as great as that of the turbojet-engined KS-1. This was because absence of an air-inlet duct enabled a much greater quantity of propellants to be carried.

In turn, this greatly increased the launch weight, and as the wing was slightly smaller the wing loading was almost doubled. Each wing had ¼-chord sweep of 55°, anhedral of –5° and two fences, and a PVD boom was mounted on the starboard tip. The wings folded immediately inboard of the ailerons. The fuselage had a large bluff-fronted radome on the nose. Next came the FK-1M or FK-2 warhead, followed by the capacious tanks of rocket propellants, with feed pipes, drains and purging pipes in a fairing along the underside of the missile.

KSR-2 carried by Tu-16 KSR of the Egyptian air force. (RART)



K-9 mockup missile loaded on Ye-152A. (Yefim Gordon archive)

Last came the guidance and equipment bay, with the rocket engine in the tailcone. Although this was a transonic vehicle, the tailplane was fixed, and provided with separate elevators.

Both missiles had the same inertial navigation system as Kh-20. The difference between the missiles lay in the guidance system used in the terminal phase. The KSR-2 had an active radar in the nose – a set related to that of K-10S, with a similar parabolic dish antenna – to guide its final dive on to the target. In contrast, KSR-11 emitted no signals but steered itself on to its target with multiwaveband passive receivers, using a dish antenna in the nose and a horizontal blade antenna at the tail, which picked up emissions from the target ship.

Prototypes of both missiles were tested in 1960, and both became operational in 1962. The *kompleks* was the K-11-16, and the Tu-16K-11-16 could thus carry and launch both types of missile. The following specification applies to both. The ASCC name was 'AS-5 Kelt'.

Span (prototypes) 4.75m, (production) 4.523m (14ft 10in), (wings folded) 2.721m (8ft 11⅛in); length (prototypes) 8.58 or 8.59m, (production) 8.647m (28ft 4½in).

Weight empty (KSR-2) 2,002kg (4,414lb); launch weight (2) 4,077kg (8,988lb).

Cruising speed (high altitude) 1,250km/h (777mph, Mach 1.18); cruise altitude 1,500–10,000m (4,920–32,800ft); range (low level) 70–150km (43.5–93 miles), (high altitude) 180–230km (112–143 miles).

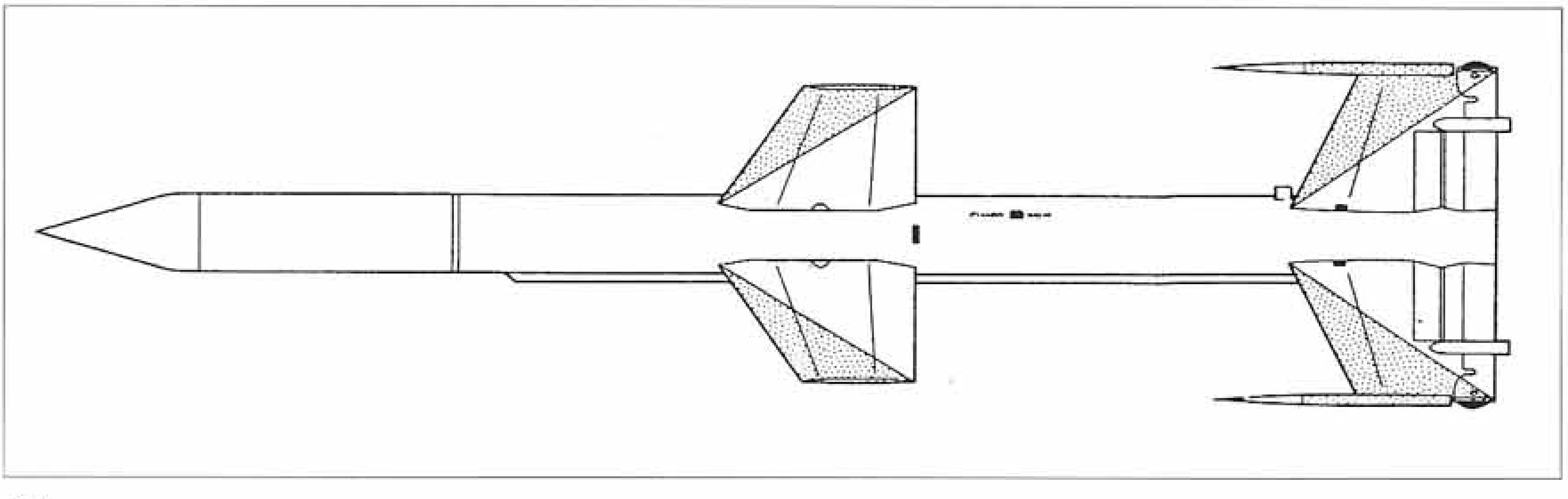
K-9

Few details are available of the OKB's only air-to-air missile. Work began in 1955, with factory designation K-155, test missiles were fired in 1957 and prototypes were seen in 1961 at the Tushino airshow, by which time development had been abandoned. The intended carrier aircraft were the Ye-150, Ye-152A, Ye-152M and Ye-152-1. The missile had a tubular body, large fully powered cruciform wings amidships and even larger cruciform tails indexed in line, with antennas and control spoilers. This missile had semiactive homing guidance as part of the *Uragan*-5 complex. The ASCC name was 'AA-4 Awl'.

Span over wings 1m (39.4in); length 4.5m (177in); body diameter 240mm (9.4in).

Launch weight 580kg (1,279lb).

Flight speed to burnout about Mach 3; range about 20km (12.4 miles).



K-9.

Appendix 1

Engines of MiG aircraft

The following is a brief listing of the engines mentioned in this book. They are in strict alphabetical order by designation or name. No attempt has been made to separate piston or turbine engines, or products designed by particular bureaux. For afterburning jet engines two thrusts are given, the first being maximum dry (MIL) thrust and the second the thrust in maximum afterburner.

AL-7 Single-shaft turbojet with nine-stage compressor designed by Arkhip M Lyul'ka. AL-7F-1 with afterburner rated at 6,240kg (13,757lb) maximum dry thrust and 9,220kg (20,326lb) with afterburner.

AL-21 Single-shaft turbojet developed from AL-7 with 14-stage compressor. AL-21F-3 with afterburner rated at 8,000/11,500kg (17,637/25,353lb).

AL-41 Two-shaft turbofan with augmentor and vectoring nozzle, in the 19,000kg (41,888lb) thrust class; minimum number of parts and high turbine entry temperature to give dry supercruise capability.

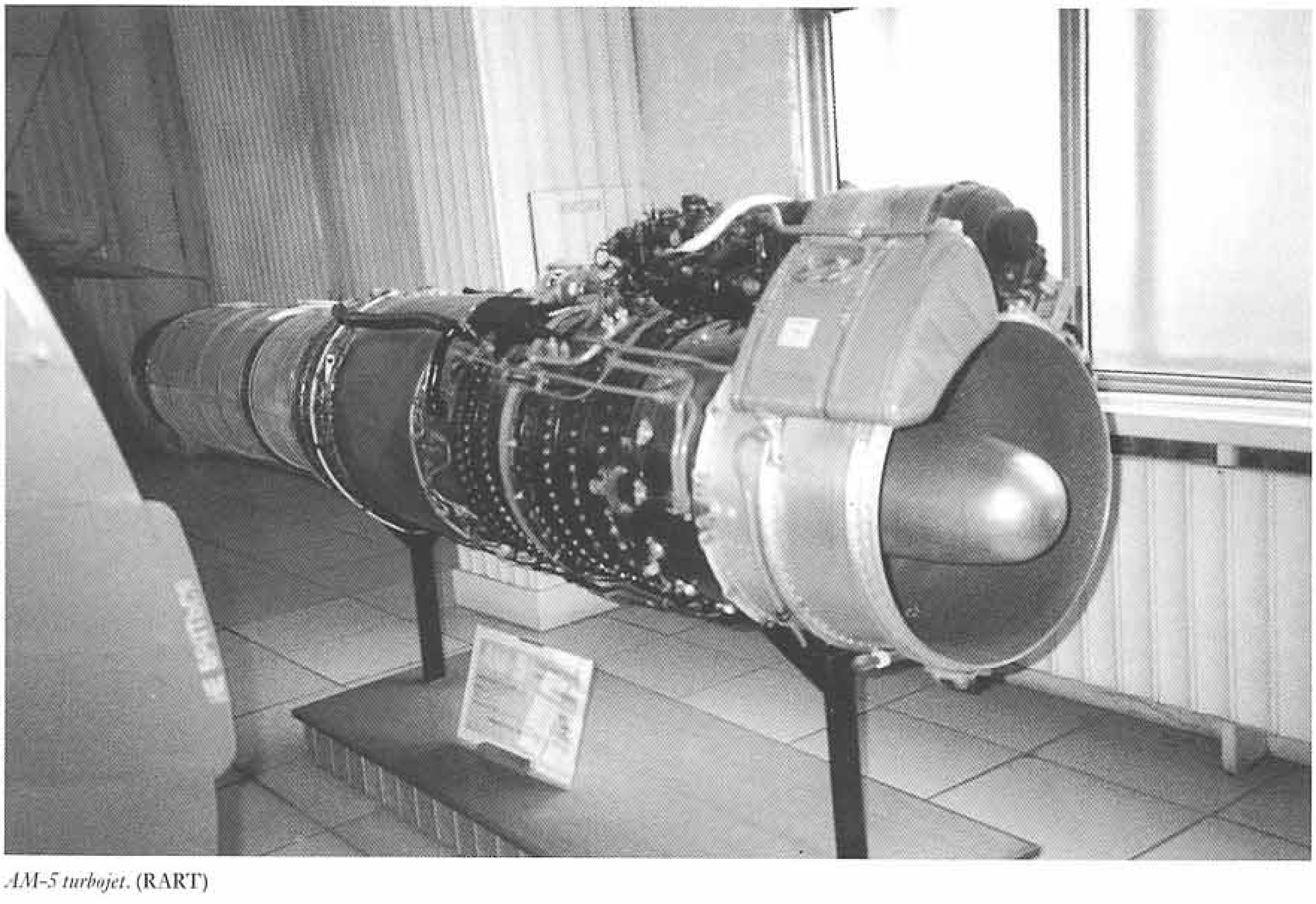
AM-5 Single-shaft turbojet of only 670mm (26.4in) diameter, qualified in 1950 at 1,900kg (4,190lb) thrust; AM-5A, 2,000kg (4,409lb); AM-5F with afterburner, 2,150/2,700kg (4,740/5,952lb); weight 624kg (1,376lb). 'AM' engines were designed by the A A Mikulin design bureau.

AM-9 *See* RD-9.

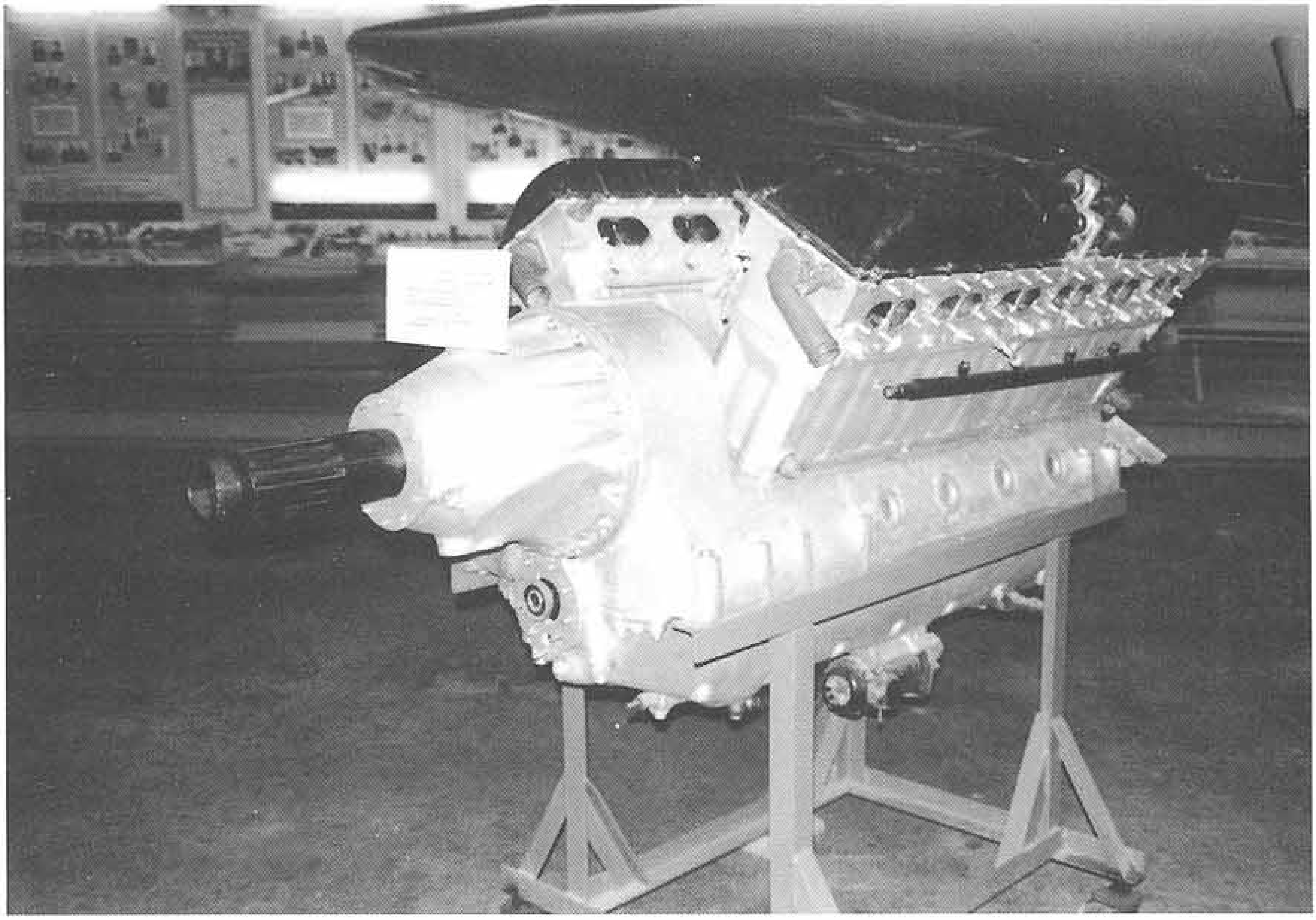
AM-11 *See* R-11.

AM-35A Piston engine, with twelve liquid-cooled cylinders in V formation; 46.66 litres (2,847cu in); 1,007kW (1,350hp); weight 830kg (1,830lb).

AM-37 Developed from AM-35, rated at 1,029kW (1,380hp); AM-37F at 1,044kW (1,400hp).



AM-5 turbojet. (RART)



AM-35A piston engine. (Bill Gunston archive)

AM-38 Refined derivative, 1,242kW (1,665hp); AM-38F rated initially at 1,268kW (1,700hp) and finally at 1,283kW (1,720hp).

AM-39 Further development, qualified in 1942 at 1,343kW (1,800hp); AM-39A with turbocharger, 1,156kW (1,550hp) for takeoff and greatly increased power at high altitude; AM-39B-1 with turbo, 1,306kW (1,750hp).

AM-42FB Further development, member of AM-42 family qualified in 1944 with turbo at 1,417kW (1,900hp) and later at 1,492kW (2,000hp).

ASh-82 *See* M-82.

BMW 003A German axial-flow turbojet, takeoff rating 800kg (1,764lb); dry weight 568kg (1,252lb).

D-30F-6 Large two-shaft augmented turbofan designed by Pavel A Solov'yov (now JSC Aviadvigatel led by Yu E Reshetnikov) for long-range supersonic aircraft, 5-stage LP and 10-stage HP compressors; 9,500kg (20,944lb) dry, 15,520kg (34,215lb) augmented; 18,980kg (41,843lb) frontal (i.e., maximum combat); weight 2,416kg (5,326lb).

D-1700 Two-shaft turbofan of 1,700kg (3,748lb) thrust under development by Aviadvigatel. Expected to begin flight testing in 2000.

DV-2 Two-shaft turbofan designed by V A Lotarev (Ukraine, then in USSR) and ZVL (Czech), now a product of Klimov Corporation (Russia) and PS Aero-Engine Division (Slovakia), 2,200kg (4,852lb).

Larzac 04-R20 Two-shaft turbofan by SNECMA and Turbomeca (both France), 1,440kg (3,175lb).

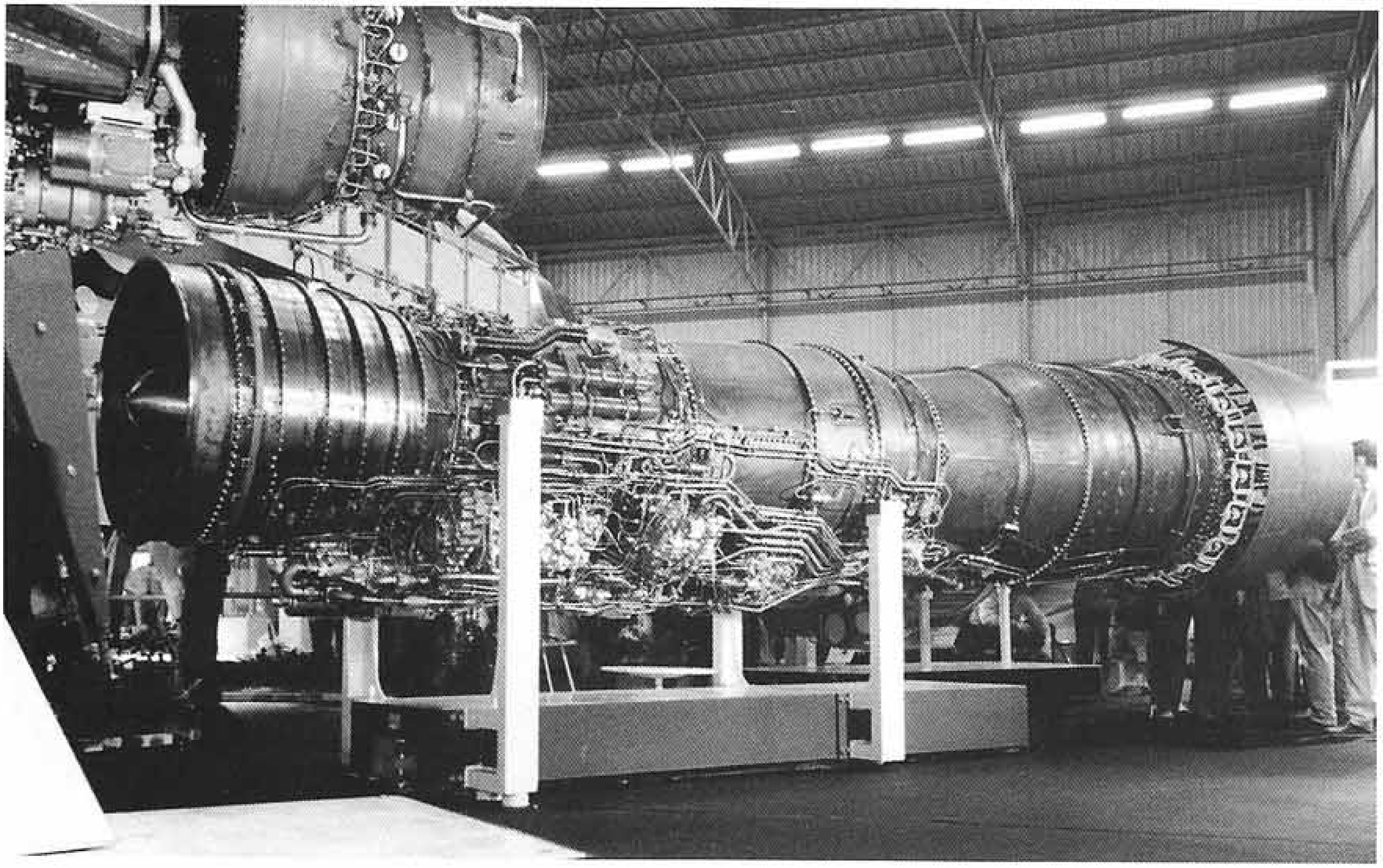
M-11F Piston engine, designer A D Shvetsov, member of vast 1927–59 family, five radial air-cooled cylinders, 82kW (110hp).

M-82 Piston engine, 14-cylinder air-cooled radial, designer A D Shvetsov; M-82A, 1,268kW (1,700hp); M-82F, 1,380kW (1,850hp). From 1942 called ASh-82.

Nene 2 Imported Rolls-Royce centrifugal turbojet, 2,270kg (5,000lb).

R3-26 Derived from RD-9 by V N Sorokin, afterburning thrust 3,800kg (8,377lb); R3M-26 same rating.

R-11 Two-shaft turbojet with afterburner, 3-stage LP, 5-stage HP, designer S K Tumanskiy but initially designated AM-11 for Mikulin; inlet diameter 825mm (32.5in); typical dry weight 1,120kg (2,469lb); R-11-300, 3,900/5,100kg (8,600/11,240lb); R-11F-300, 3,900/5,740kg (8,600/12,654lb); R-11F2-300, 3,950/6,120kg (8,708/13,492lb); R-11F2S-300 for blown flaps, 3,900/6,175kg (8,600/13,613lb).



D-30F-6 augmented turbofan. (Bill Gunston archive)

R-13 Two-shaft turbojet with afterburner, 3 + 5 stages, developed from R-11 by S A Gavrilov, R-13-300, 4,070/6,490kg (8,973/14,308lb).

R-15 Single-shaft turbojet with afterburner for Mach-3 aircraft, chief designer S K Tumanskiy, 5-stage compressor; inlet diameter 996mm (39.2in); typical dry weight 2,590kg (5,710lb); R-15-300, 6,840/10,150kg (15,080/22,380lb); R-15B-300, 7,500/10,210kg (16,535/22,510lb); R-15BD-300, 8,800/11,200kg (19,400/24,700lb); R-15-BF2-300, 8,800/ 13,500kg (19,400/29,760lb); all ratings on T-6 anticoking fuel able to soak in tanks heated by Mach-3 slipstream.

R-21 Two-shaft turbojet with afterburner derived from R-11F by N Metskhvarishvili, with increased diameter, 4,700/7,200kg (10,360/15,875lb).

R-25 Two-shaft turbojet with afterburner designed by S A Gavrilov, rebladed 3 + 5-stage compressors, dry weight 1,210kg (2,668lb); 4,100/7,100kg (9,040/15,650lb).

R-27 Growth derivative of R-11/R-13/R-25 by K Khachaturov, 5 + 6 stages; R-27–300, 5,200/7,800kg (11,464/17,196lb); R-27F-300, 6,500/9,690kg (14,320/21,365lb); R-27F2M-300, 6,900/10,000kg (15,210/22,050lb).

R-29 Uprated derivative of R-27 by Khachaturov; diameter 912mm (35.9in); dry weight 1,880kg (4,145lb); R-29-300, 8,300/12,500kg (18,300/27,560lb); R-29B-300 low-level engine with simplified afterburner, 8,000/11,500kg (17,635/25,250lb).

R-35 Further development by Khachaturov; diameter as R-29; dry weight 1,765kg (3,891lb); R-35-300, 8,550/13,000kg (18,850/28,660lb).

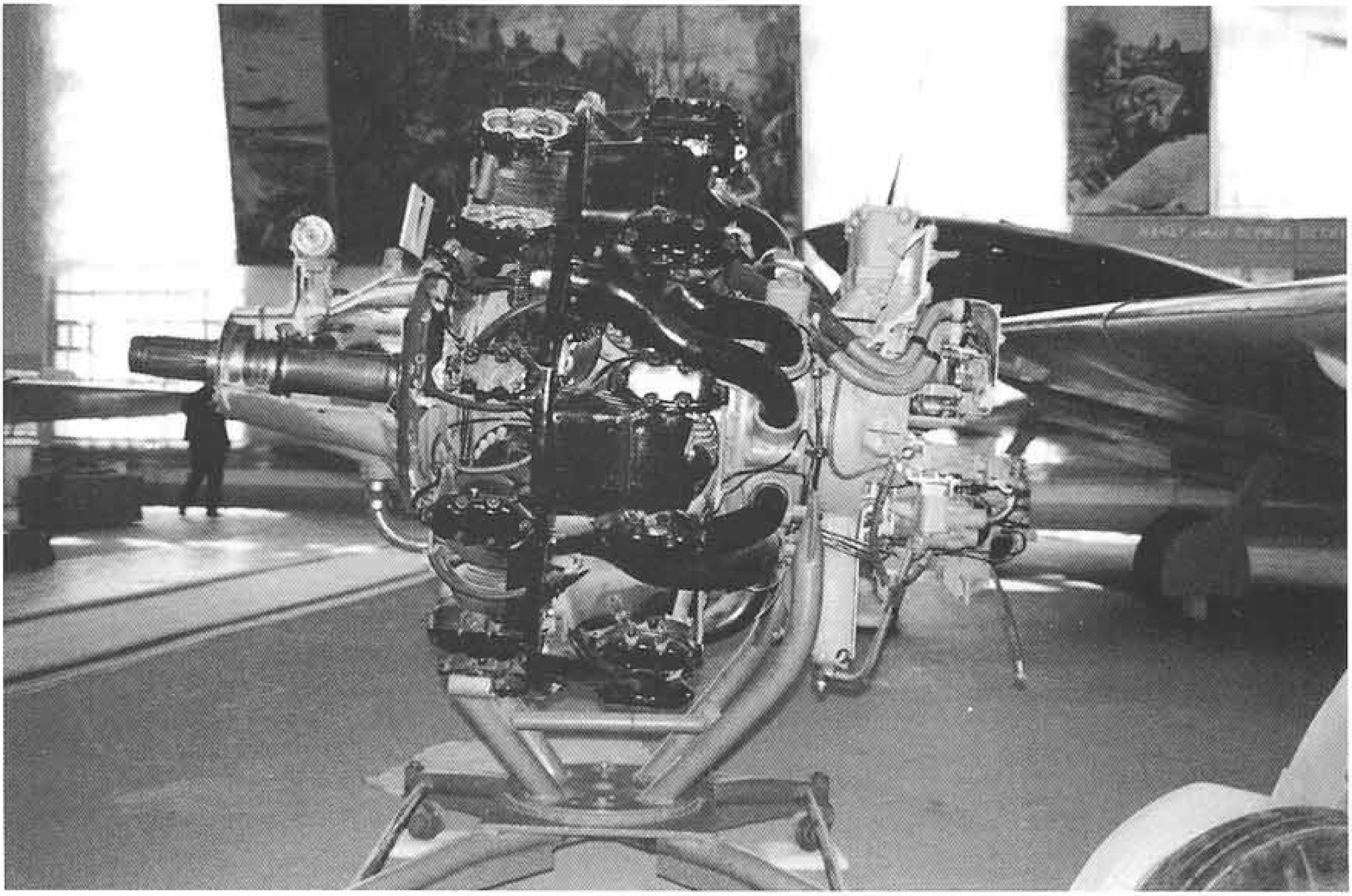
RD-2M-3V Liquid-propellant rocket engine by L S Dushkin and V P Glushko, main chamber 1,050kg (1,400kg at altitude), auxiliary chamber 400kg (2,315/3,086lb and 882lb).

RD-9 Single-shaft turbojet with afterburner, 9-stage compressor, designer S K Tumanskiy but initially designated AM-9 for Mikulin; diameter 668mm (26.3in); dry weight (BF-811) 725kg (1,598lb); RD-9B and RD-9BM, 2,600/3,250kg (5,732/7,165lb); RD-9BF2-300, 2,600/3,300kg (5,732/7,275lb); RD-9BF-811, 2,790/3,750kg (6,150/8,267lb); RD-9Ye afterburning rating, 3,800kg (8,377lb); RD-9K missile engine, rating unknown.

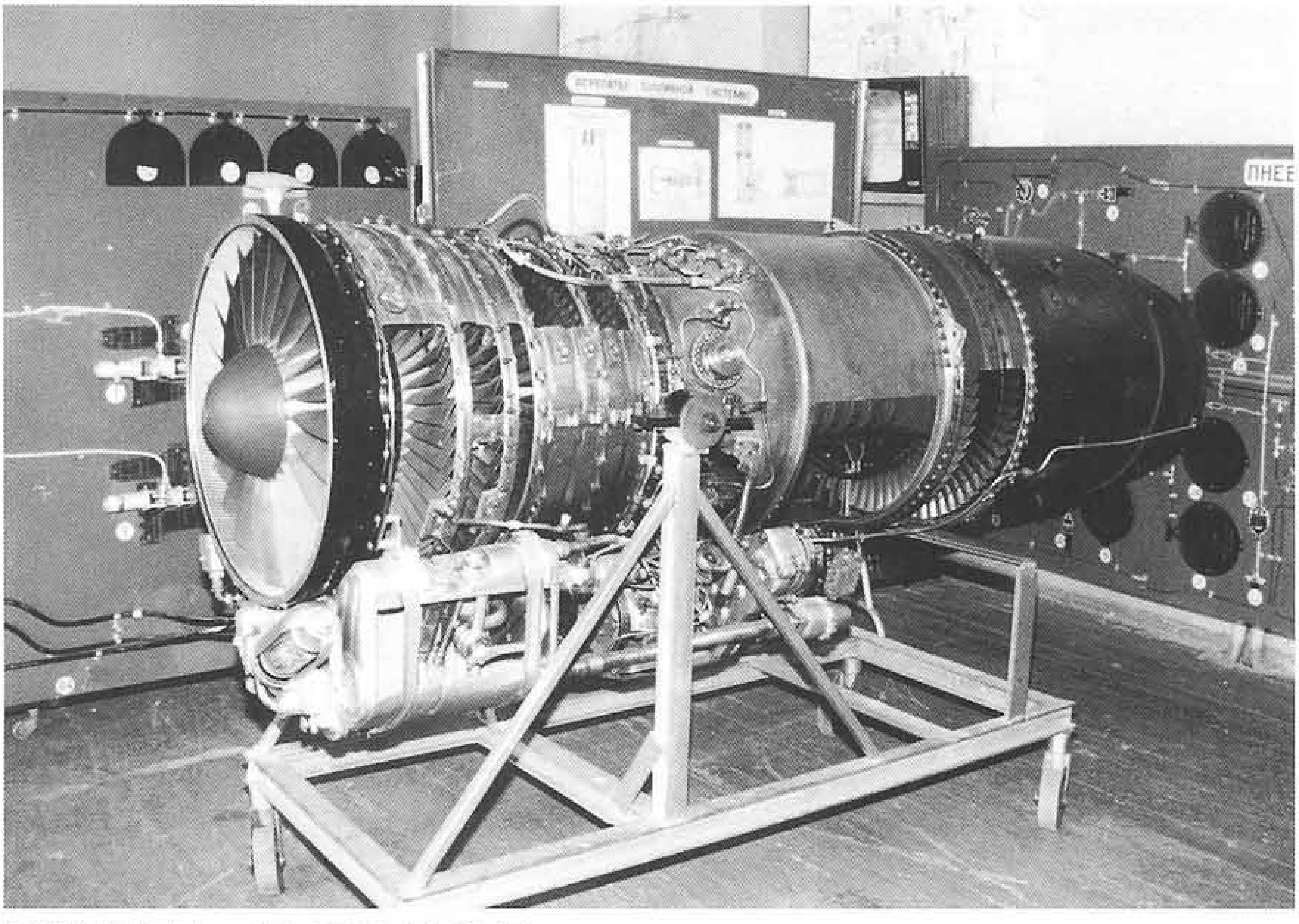
RD-20 Soviet-built BMW 003A, 800kg (1,764lb); RD-20F, later redesignated RD-21, increased turbine entry temperature, 1,000kg (2,205lb).

RD-33 Two-shaft turbofan with augmentor, 4 + 9 stages, designed by S P Isotov, later developed by V Styepanov (briefly) and A A Sarkisov; diameter 1,000mm (39.37in); dry weight 1,055kg (2,326lb); mass flow 76kg (167.5lb)/s; ratings 5,040/8,300kg (11,110/18,300lb). Series 1 TBO 400hr, Series 2, 800hr, Series 3, 1,000hr; RD-33K, mass flow 77kg (170lb)/s; ratings 5,500/8,770kg (12,125/19,334lb); *see* RD-133.

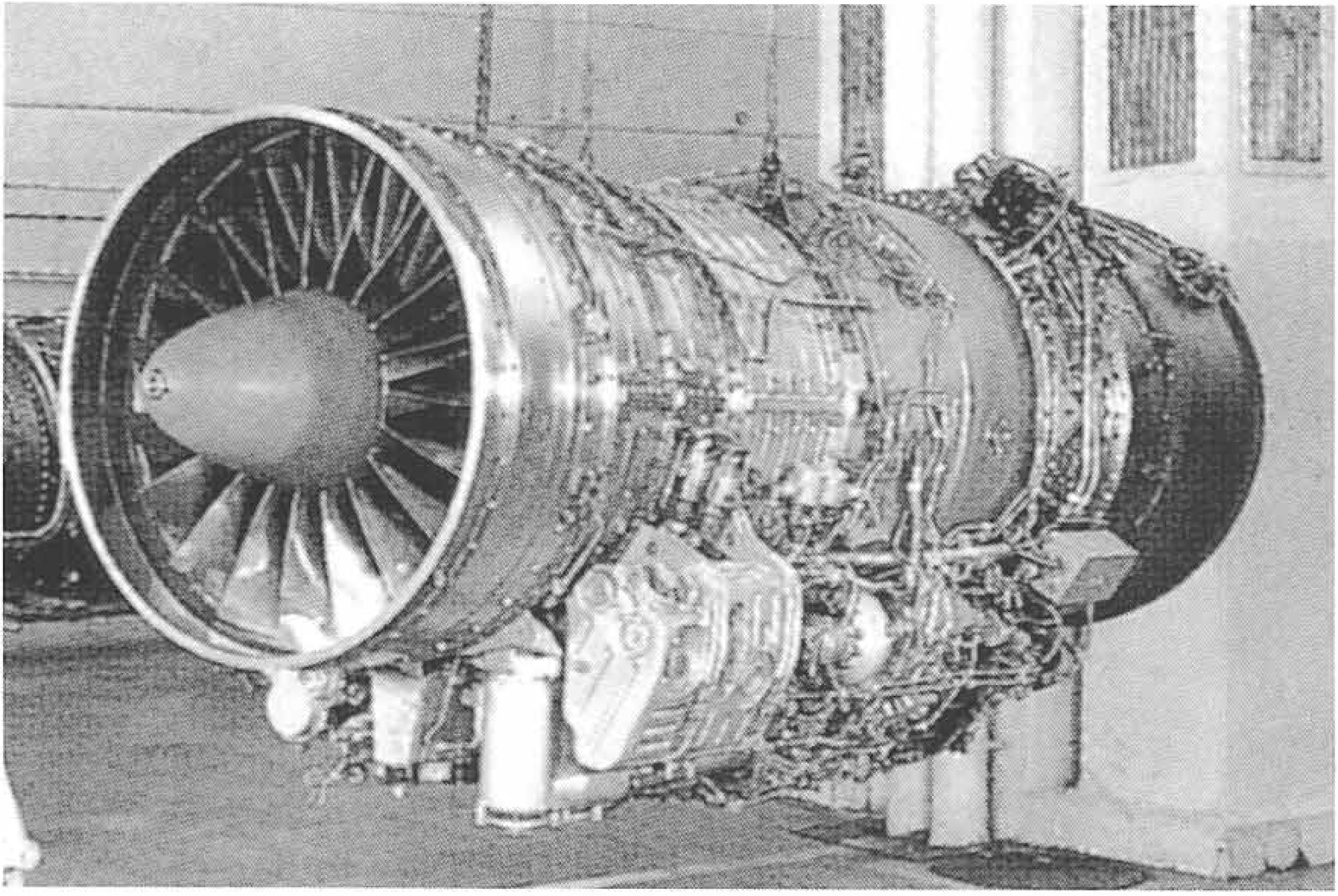
RD-36-35 Simple turbojet to help lift V/STOL aircraft, 6-stage compressor, designer P A Kolesov, 2,350kg rating



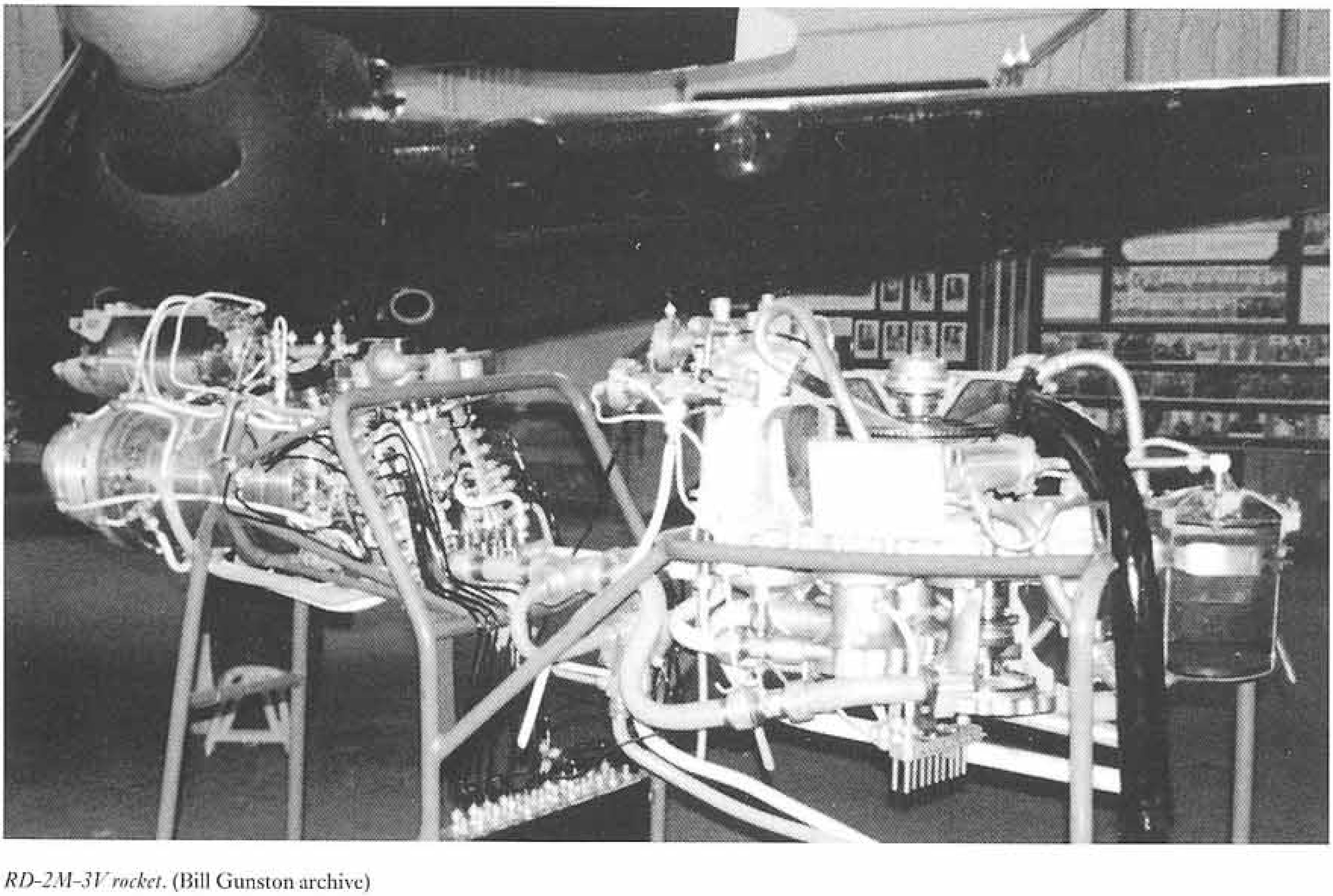
M-82A piston engine (part sectioned). (Bill Gunston archive)



R-11F2S-300 (part cutaway). (photograph by Yefim Gordon)



R-29B-300 with afterburner removed. (Hindustan Aeronautics)



RD-2M-3V rocket. (Bill Gunston archive) but when used as propulsion engine in 105-11 derated to 2,000kg (4,409lb).

RD-45 Soviet copy of Rolls-Royce Nene 2; diameter 1,258mm (49.5in); dry weight 814kg (1,795lb); initially rated at 2,200kg (4,850lb), later RD-45F 2,270kg (5,004lb).

RD-133 Essentially an RD-33K with fully variable 3-D vectoring nozzle with FADEC or mechanical control; TBO to be 2,000hr. Designed for retrofit to all MiG-29 versions.

RD-333 Completely new two-shaft augmented turbofan with 3-D vectoring nozzle, designed for retrofit to MiG-29. Mass flow 85kg (187lb)/s, turbine gas temperature 1,800K (2,073°C, 3,763°F), augmented rating 10,000kg (22,046lb). Bench testing due 1999.

RD-500 Soviet copy of Rolls-Royce Derwent 5 single-shaft centrifugal turbojet, 1,590kg (3,505lb); RD-500K missile engine rating, unknown.

RU-013 Controllable liquid-propellant rocket engine, designer D D Sevruk, two thrust levels (sea level), 1,300 or 3,000kg (2,866 or 6,614lb).

S-3 Liquid-propellant rocket engine, designer L S Dushkin; S-3/20M5A sea-level rating, 3,000kg (6,614lb).

S-155 Liquid-propellant rocket engine, designer L S Dushkin, sea-level rating, 1,300kg (2,866lb).

SMR-95 Version of RD-33 by Aerosud (South Africa) and Marvol (Russia) for retrofit to MiG-21 and Mirage, performance unchanged.

TR-1A Single-shaft turbojet with 8-stage compressor, designer A M Lyul'ka, qualified 1946 at 1,300kg (2,866lb), uprated in 1947 to 1,500kg (3,307lb).

TR-3A Single-shaft turbojet by Lyul'ka, qualified in 1950 at 4,500kg (9,921lb), uprated in 1951 to 4,600kg (10,141lb).

TV7-117 Family of shaft-drive engines produced by Klimov Corporation, first version in production is TV7-117S turboprop, 1,839kW (2,466shp) flat-rated to 35°C.

TVD-1500 Family of shaft-drive engines produced by Rybinsk engine-building design office, baseline engine is TVD-1500S turboprop rated at 970kW (1,300shp).

U-19D Designation of booster package containing RU-013 rocket engine.

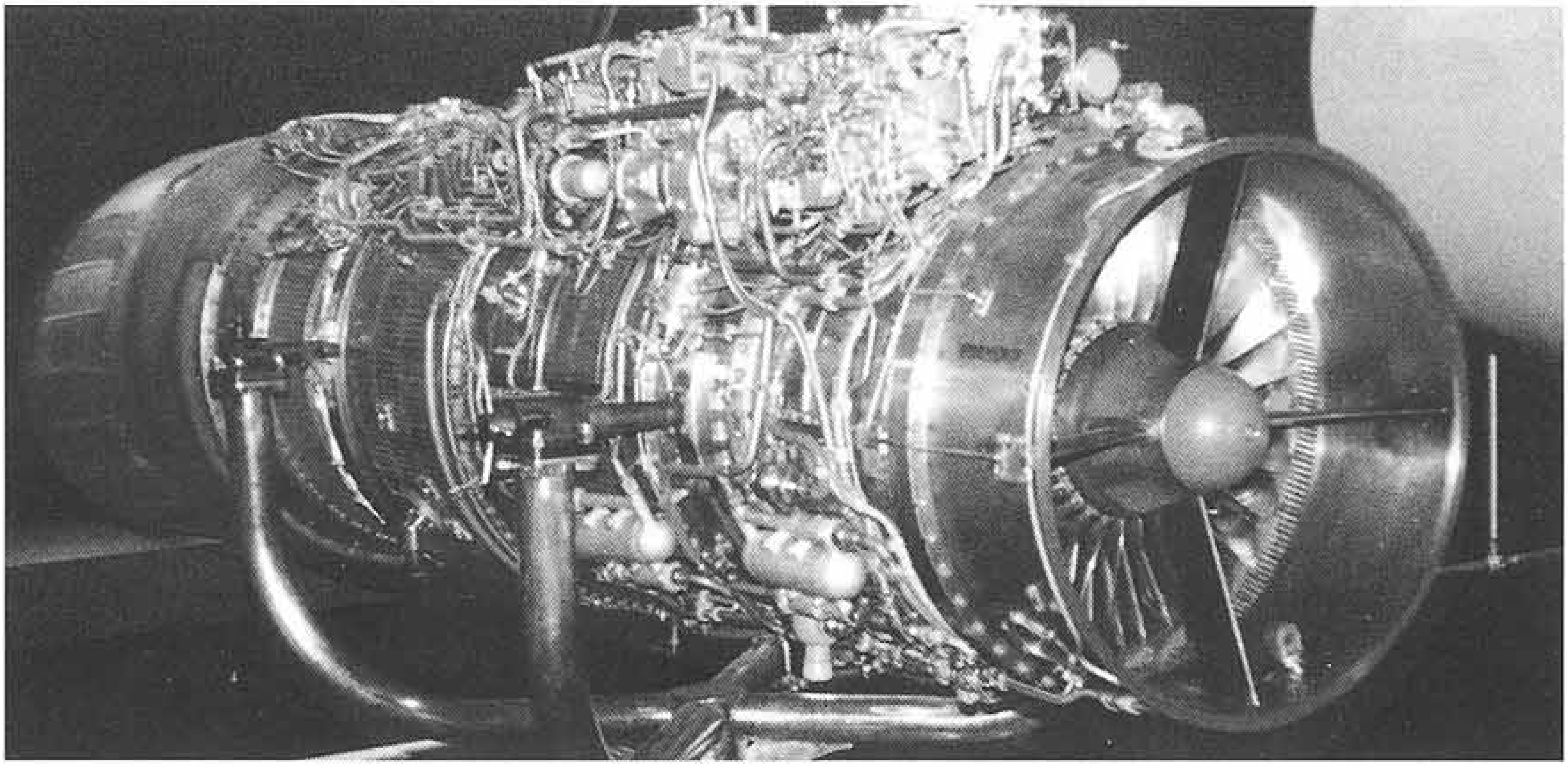
VK-1 Soviet centrifugal turbojet developed by V Ya Klimov from RD-45F; diameter 1,273mm (50.1in); dry weight (typical, without afterburner) 872kg (1,922lb); VK-1 rating 2,700kg (5,952lb); VK-1A, same rating, longer life; VK-1F fitted with afterburner, 2,600/3,380kg (5,732/7,452lb).

VK-3 Single-shaft bypass turbojet (low-ratio turbofan) with afterburner, designer S V Lyunevich in Klimov bureau, 5,730/8,440kg (12,632/18,607lb).

VK-5F Centrifugal turbojet with afterburner developed from the VK-1 by Klimov KB, qualified 1952 at 3,000/3,850kg (6,614/8,490lb).

VK-7 Centrifugal turbojet with afterburner resembling scaled-up VK-1F, initial ratings 3,525/5,235kg (7,771/11,541lb), later uprated to 4,200/6,270kg (9,259/13,828lb).

VK-107A Piston engine with twelve liquid-cooled cylinders, designer V Ya Klimov, 1,231kW (1,650hp); boosted by VRDK system to equivalent of 1,865kW (2,500hp).



RD-33 augmented turbofan. (RART)

Appendix 2

Armament of MiG aircraft

This listing is divided into guns and guided missiles. The weapons are those with which MiG aircraft were normally equipped, and excludes experimental installations which were tested on MiG aircraft. Both lists are in alphabetical order by designation, ignoring the design bureau or the date at which the weapon was accepted for service (which is listed).

Guns

A-12.7 1953, heavy machine-gun of 12.7mm calibre, gun weight 25.5kg (56.2lb), cyclic rate of fire 1,100r/min; projectile mass 48g, muzzle velocity 820m/s (2,690ft/s).

GSh-23 1961, twin-barrel gun of 23mm calibre, 50.5kg (111lb), 3,600r/min; projectile 186g, 735m/s (2,411ft/s).

GSh-6-23 1973, 6-barrel rotary gun of 23mm calibre, 195kg (430lb), choice of two rates of fire, 6,000 or 8,000r/min; projectile 186g, 700m/s (2,297ft/s).

GSh-6-30 1971, 6-barrel rotary gun of 30mm calibre, 290kg (639lb), 4,000r/min; projectile 410g, 780m/s (2,559ft/s).

GSh-30/I 1979, single-barrel gun of 30mm calibre, 50kg (110lb), 1,800r/min; projectile 410g, 860m/s (2,822ft/s).

N-37 1946, cannon of 37mm calibre, 103kg (227lb), 400r/min; projectile 735g, 900m/s (2,953ft/s).

N-57 1944, cannon of 57mm calibre, 290kg (639lb), 180r/min; projectile 2.78kg, 980m/s (3,215ft/s).

NR-23 1949, cannon of 23mm calibre, 39kg (86lb), 950r/min; projectile 200g, 690m/s (2,264ft/s).

NR-30 1954, cannon of 30mm calibre, 66.5kg (146.6lb), 900r/min; projectile 410g, 780m/s (2,559ft/s).

NS-23 1945, cannon of 23mm calibre, 37kg (81.6lb); 550r/min; projectile 200g, 690m/s (2,264ft/s).

ShKAS 1932, rifle-calibre (7.62mm), 10.6kg (23.4lb); 1,800r/min; projectile 9.6g, 825m/s (2,707ft/s).

ShVAK 1936, cannon of 20mm calibre, 42kg (92.6lb); 800r/min; projectile 96g, 800m/s (2,625ft/s).

UB 1940, heavy machine-gun of 12.7mm calibre: UBK for wing mounting, weight 21.41kg (47.2lb), 1,050r/min; UBS for synchronized installation, 21.45kg (47.29lb), 800r/min; both fired 48g projectile at 850m/s (2,789ft/s).

Guided Missiles

Air-to-air

K-6 1955, OKB-2 P D Grushin, roll control by ailerons, guidance by tail controls, lateral motor nozzles to leave streamlined tail free for receiver antenna. Prototypes only.

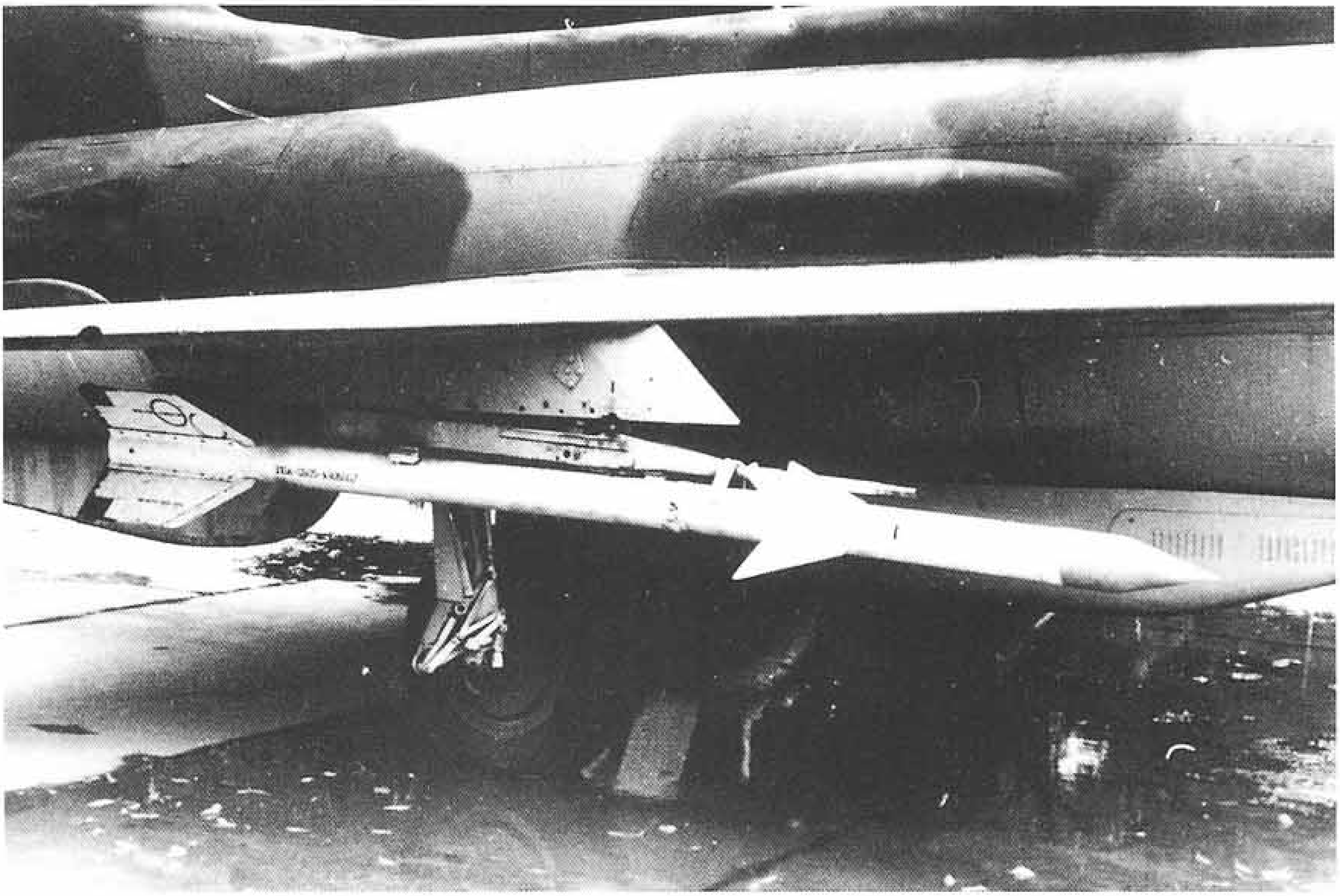
K-9 Described previously in section on MiG missiles.

R-3 1960, *kompleks* K-13, large family of short-range missiles derived from United States Sidewinder by OKB-134 (Toropov), body diameter 127mm (5in), warhead 11.5kg (25.4lb); R-3S, IR-homing, 75.3kg (166lb), length 2.84m (112in), range 0.8–7km; R-3R, semiactive radar, 83.5kg (184lb), length 3.417m (134.5in), range 1.9–14km; R-13M, IR-homing, 90kg (198.4lb), length 2.87m (113in), range 10–13km. ASCC name 'Atoll'.

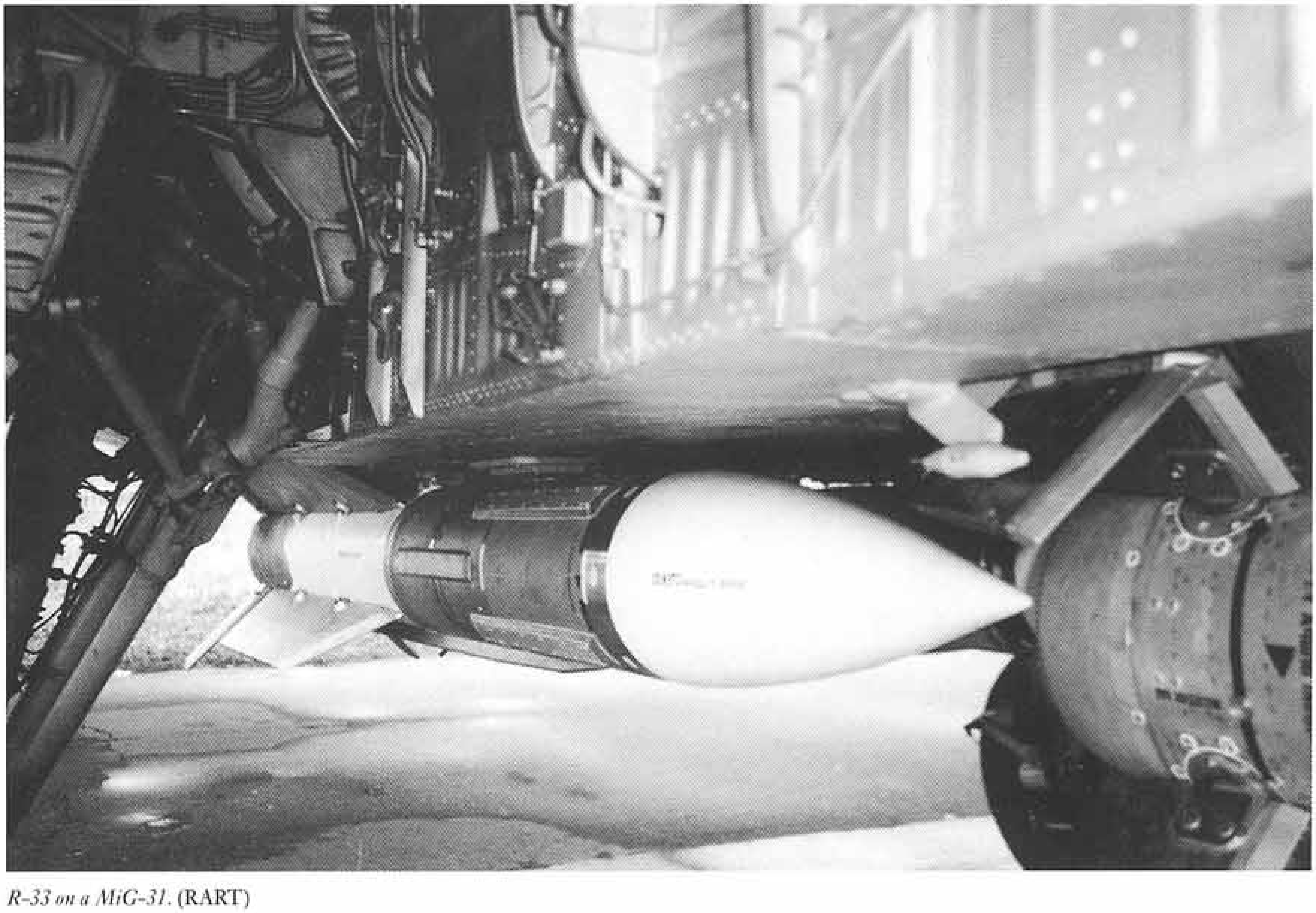
R-4 1965, *kompleks* K-80, Bisnovat KB, body diameter 315mm (12.4in), warhead 50kg (110lb); R-4R, semiactive radar, 494kg (1,089lb), length 5.4m (212.6in), range 2–40km; R-4T, IR-homing, 480kg (1,058lb), 5.2m (204.7in), range up to 15km. ASCC name 'Ash'.

R-8 1958–65, *kompleks* K-8, M R Bisnovat, body diameter 275mm (10.8in), length 4.27m (168in); R-8MR semiactive, 275kg (606lb), R-8MT, IR-homing, 227kg (500lb), large family developed into R-30 and R-98 versions. ASCC name 'Anab'.

R-23 From 1970, *Izdeliye* 340 or 360, Vympel SKB, body diameter 200mm (7.9in), warhead 25kg (55lb), R-23R,



R-13M. (RART)



R-33 on a MiG-31. (RART)

semiactive radar, 223kg (491.6lb), length 4.46m (175.6in), range 25–35km; R-23T, IR-homing, 217kg (478.4lb), length 4.18m (164.6in), range 19–35km. ASCC name 'Apex'.

R-24 1981, *Izdeliye* 140 or 160, advanced versions of R-23, body diameter 230mm (9.06in), length 4.8m (189in), warhead 25kg (55lb), R-24R, radio command plus semiactive radar, 250kg (551lb), range 30–42km; R-24T, IR-homing, 248kg (546.7lb), range 25–35km. ASCC name 'Apex'.

R-27 From 1983, *Izdeliye* 470, GosMKB Vympel, body diameter 230mm (9.06in), warhead 39kg (86lb); R-27R, radio command plus semiactive radar, 253kg (558lb), length 4.08m (160.6in), range 0.5–80km; R-27T, IR-homing, length 3.795m (149.4in), 245kg (540lb), range 0.5–70km. ASCC name 'Alamo'.

R-27E 1985–86, upgraded and enlarged, body diameter 260mm (10.24 in), warhead 39kg as before; R-27ER, (R-27RE), radio command plus semiactive radar, 350kg (771.6lb), length 4.78m (188.2in), range 0.5–130km; R-27ET (R-27TE), IR-homing, 348kg (767lb), length 4.5m (177in), range 0.5–120km. ASCC name 'Alamo'.

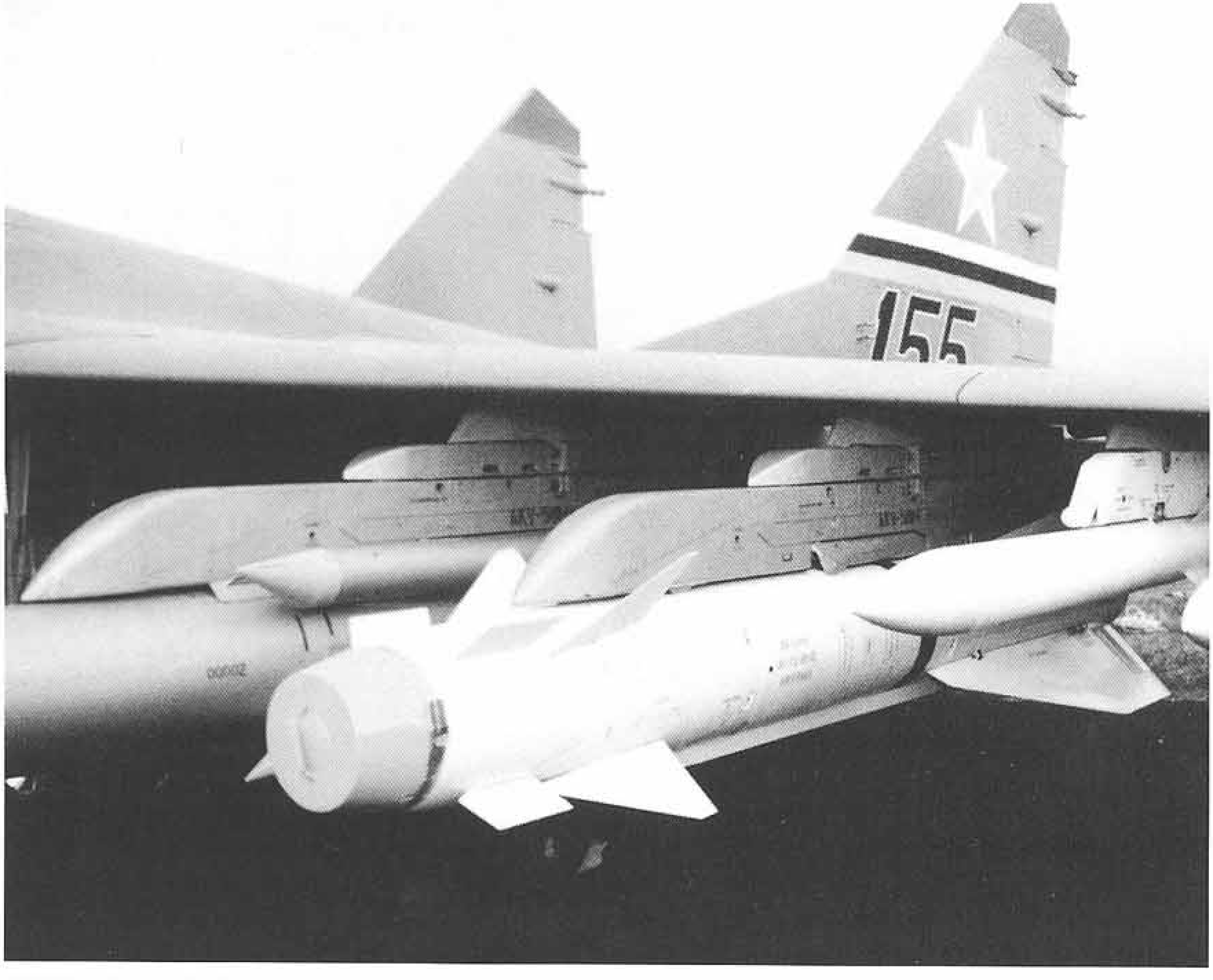
R-33 December 1981, GosMKB Vympel, body diameter 380mm (15in), warhead 47kg (103.6lb), radio command plus semiactive radar homing, 488kg (1,075.8lb), length 4.15m (163.4in), range 120km. ASCC name 'Amos'.

R-40 1970, *kompleks* K-40, K-40D, SKB Vympel, M R Bisnovat, body diameter 300mm (11.8in), warhead 40kg (88.2lb); R-40R, semiactive radar, 685kg (1,510lb), length 6.3m (248in), range 35–72km; R-40T, IR-homing, 606kg (1,336lb), length 5.8m (228in), range 20–30km; R-40TD, as R-40T but range 50km. ASCC name 'Acrid'.

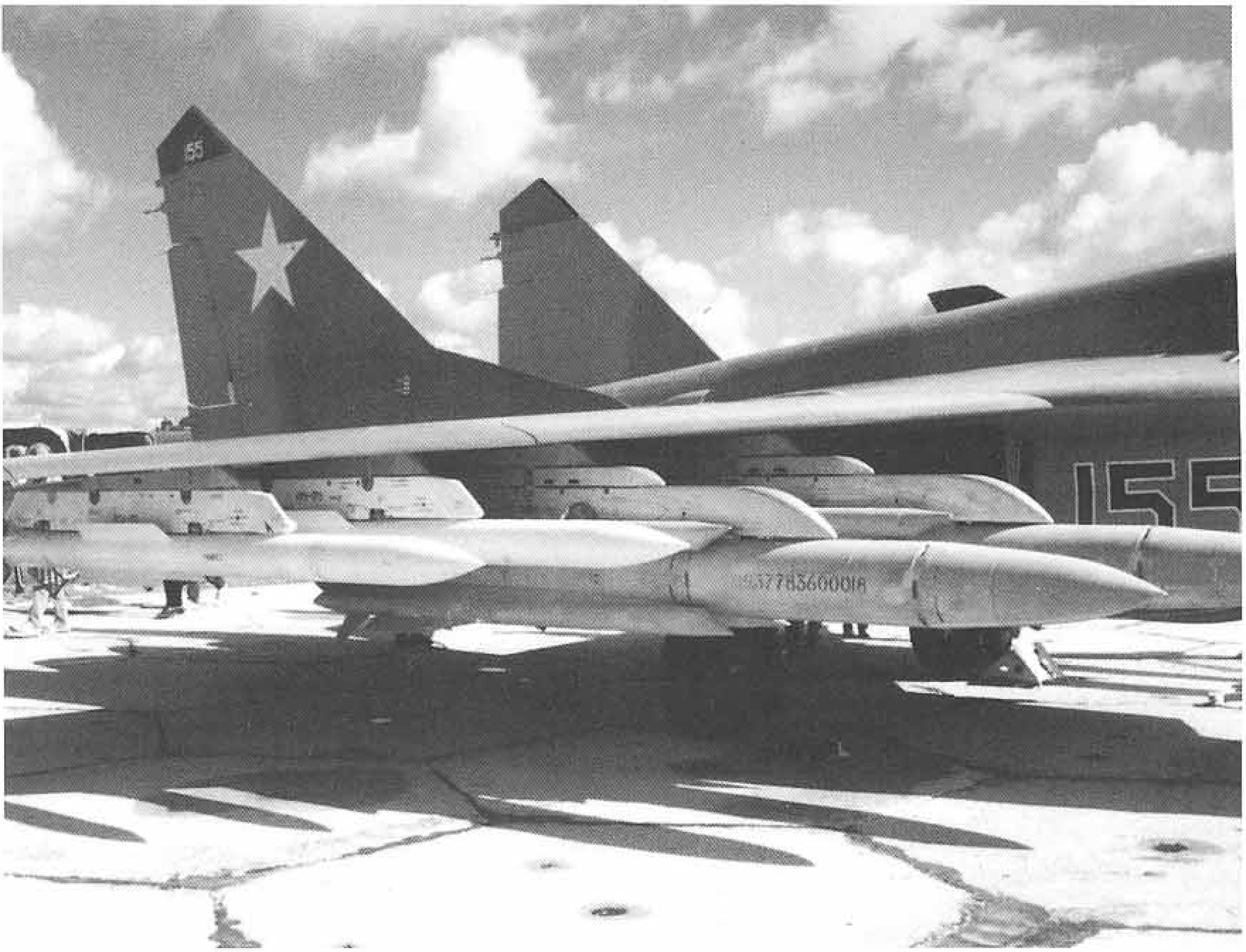
R-60 1967, *Izdeliye* 62, SKB then GosMKB Vympel, body diameter 120mm (4.724in), warhead 3.5kg (7lb); length 2.1m (82.7in), 45 kg (99lb), range 0.5–10km; R-60M, 1978, length 2.096m (82.5in), 43.5kg (95.9lb), range up to 10km. ASCC name 'Aphid'.

R-73 1982, *Izdeliye* 72, 72E, GosMKB Vympel, IR-homing, body diameter 170mm (6.7in), warhead 8kg (17.6lb), length 2.89m (113.8in), 105kg (231.5lb), range 0.3–30km; R-73E, 1984, 90° off-boresight, doubled IR lock-on range, similar characteristics. ASCC name 'Archer'.

R-77 1991, *kompleks* K-77 (RVV-AE), GosMKB Vympel, active radar homing, body diameter 200mm (7.9in), length 3.6m (141.7in), warhead 25kg (55lb), 175kg



Kh-29T and (outboard) R-77s under the port wing of a MiG-29M. (RART)



Two Kh-31A inboard and two R-77 outboard on a MiG-29M. (RART)

(386lb), range 0.5–95km (R-77 Mod, to over 100km). Production delayed (no funds) until 1997.

RS-2U 1952–57, *kompleks* K-5 (*Izdeliye* 1) and K-51, OKB-2, P D Grushin, radio command, body diameter 200mm (7.9in), warhead 13kg (28.6lb); RS-1U, 82.5kg (182lb), length 2.5m (98.43in), range 2–6km; RS-2US, 83.2kg (183.4lb), length 2.838m (111.7in), range 6km. ASCC name 'Alkali'.

Air-to-surface

Kh-23 1968, *'Grom' Izdeliye* 68, KB Zvezda, radio command, 286kg (630.5lb), warhead 108kg (238lb), body diameter 270mm (10.6in), range 10km; Kh-23M, 1973, upgraded guidance. ASCC name 'Kerry'.

Kh-25 1973, *Izdeliye* 69, KB Zvezda, body diameter 275mm (10.83in), warhead (except MR) 90kg (198lb); Kh-25ML, 24N1 laser homing, 300kg (662lb), range 10–20km; Kh-25MP, passive homing on hostile emissions, 310kg (683.4lb), range 25–60km; Kh-25MR, radio command, 320kg (705.5lb), warhead 140kg (308.6lb), range 8km; Kh-25MT, TV guidance, 300kg (662lb), range 2–20km; Kh-25MTL, thermal imaging, 300kg (662lb), range 2–20km. ASCC name 'Karen'.

Kh-27 1973, upgrades of Kh-23M family, similar specifications. ASCC name 'Kerry'.

Kh-29 1980, *Izdeliye* 64L, 64T, GosMKB Vympel, body diameter 380mm (14.96in); Kh-29L, laser homing, 660kg (1,455lb), warhead 317kg (699lb), range 8km; Kh-29T, TV guidance, 700kg (1,543lb), warhead 320kg (705.5lb), range 20–30km. ASCC name 'Kedge'.

Kh-31 1988, KB Zvezda, 600kg (1,323lb), body diameter 360mm (14.2in), warhead 90kg (198lb); Kh-31A, active radar homing, range 5–70km; Kh-31P, passive homing on hostile emissions, range 100km. ASCC name 'Kegler'.

Kh-58 Not yet certified, MKB Raduga, passive homing on hostile emissions, body diameter 380mm (14.96in); 650kg (1,433lb); Kh-58U warhead, 150kg (330.7lb), range 10–160km; Kh-58E warhead, 149kg (328.5lb), range 10–120km. ASCC name 'Kilter'.

Kh-66 1968, *Izdeliye* 66, KB Zvezda, radio command, derivative of Kh-23, 278kg (613lb), body diameter 270mm (10.6in), warhead 103kg (227lb), range 8km. ASCC name 'Kerry'.

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